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<b>(21) International Application Number:</b> PCT/US98/05238 <b>(22) International Filing Date:</b> 17 March 1998 (17.03.98)  <b>(30) Priority Data:</b> 08/933,416 18 September 1997 (18.09.97) US PCT/US97/16543 18 September 1997 (18.09.97) US  <b>(71) Applicant (for all designated States except US):</b> MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> MELANCON, Kurt, C. [US/US]; 6480 North 125 Street, White Bear Lake, MN 55110 (US). CLANTON, Anthony, R. [US/US]; 3487 Commonwealth Avenue, Woodbury, MN 55125 (US). LOWE, Robert, H. [US/US]; 9625 Brookview Road, Woodbury, MN 55125 (US). SCHROEDER, Kristin [US/US]; 3050 Sandy Hook Drive, Roseville, MN 55113 (US).  <b>(74) Agents:</b> KNECHT, Harold, C., III et al.; Minnesota Mining and Manufacturing Company, Office of Intellectual Property Counsel, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> ADHESIVELY-BONDED INFLATABLE RESTRAINT AND METHOD OF MAKING  <b>(57) Abstract</b>  An adhesively-bonded inflatable restraint and a method of making such a restraint are disclosed. The inflatable restraint of the present invention has a substantial portion of at least one structural seam bonded with an adhesive selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, ethylene/acrylic acid adhesives, polyurethane adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin rubber adhesives, epoxy/polyolefin adhesives, polyamide adhesives, polyurea adhesives and combinations thereof, where the adhesive is formulated and prepared such that at least one structural seam bonded with the adhesive is capable of withstanding inflation forces resulting from deployment of the inflatable restraint. An inflatable protection device which includes an adhesively-bonded inflatable restraint is also disclosed.		

## ADHESIVELY-BONDED INFLATABLE RESTRAINT AND METHOD OF MAKING

### Field of the Invention

5           This invention relates to inflatable restraints such as, for example, those used in passenger vehicles, more particularly, to such restraints having seams that are adhesively bonded and, even more particularly to such restraints with seams having a lap-shear geometry that are adhesively-bonded.

### 10   Background of the Invention

          Current passenger vehicles are equipped with inflatable restraints. Examples of inflatable restraints include driver and passenger airbags, side impact bags, knee bolsters, head liner curtains, inflatable seat belts and the like. Recently, government regulations have forced automobile manufacturers to equip passenger cars and  
15   trucks with driver and passenger side airbags. Inflatable restraint systems are complex and add significantly to the final cost of the automobile. In order to meet demand, size, and cost constraints, automobile manufactures continue to investigate ways to manufacture inflatable restraint systems more efficiently and to use materials that are lighter and have a lower cost.

20           Inflatable restraints such as, for example, airbags are commonly made from woven nylon materials such as nylon 6 and nylon 6,6, or woven polyester materials such as polyethylene terephthalate. The fabric can be coated or uncoated. Commonly used coating materials are neoprene and more recently, silicone polymers. The coatings enhance the slip coefficient of the fabric so as to facilitate a  
25   smooth and rapid deployment, provide heat shielding and ablative protection to the fabric from hot gases from the inflator, and prevent gases from escaping prematurely by sealing fabric pores. Inflatable restraints are usually inflated very rapidly, for example in about 10 to 55 milliseconds, at a pressure of from 5 to about 20 psi (34.5 to 138 kPa).

30           Airbags and other inflatable restraints are typically made by cutting patterns of material and then sewing the resulting pieces together. Dimensional tolerances

are kept very tight and must be achieved with accuracy to very specific orientations. The threads used to sew the pieces together must also be of the proper fiber, weight, construction, and have the proper coating for the application. The placement of the sewing patterns and stitches is also critical to the performance of the inflatable restraint. Typical sewn seams are formed by placing the two pieces of fabric on top of one another, with the edges aligned, and then stitching the pieces of material together at or near the edges. A sewn airbag is normally turned inside out so that the sewn seams or the raw edges of the fabric are contained within the interior of the airbag, and thereby unseen.

One disadvantage of sewn seams having the above "conventional seam geometry" is that the manufacturing process for such pieces is labor intensive. Another disadvantage of stitched airbags is that during deployment of the airbag, the stitches may cause the threads of the airbag fabric to stretch and form holes in the area stitched which can lead to leakage or deployment failure. This is known in the industry as "combing." Another disadvantage of sewn airbags is that the fabric used must be of a sufficient density yarn tenacity, or weight to prevent or minimize combing of the seams. Often, the weight of material needed for sewn seams exceeds the weight needed to otherwise provide an effective inflatable restraint.

While attempts at addressing these disadvantages have been made, there is a continuing need for a relatively inexpensive inflatable restraint that overcomes the disadvantages associated with sewn seams while remaining reliable.

### **Summary of the Invention**

The invention relates to an improved inflatable restraint in which at least one structural seam, and optionally other structural and nonstructural seams, as well as other portions of the restraint, are bonded or reinforced with an adhesive.

In one aspect of the present invention, an inflatable restraint is provided which includes an inflatable chamber comprising at least one sheet of a material suitable for use in an inflatable restraint and one or more structural seams. Each structural seam is formed by at least two sheet edges. The inflatable chamber has a substantial portion of at least one structural seam bonded with an adhesive selected

such that the at least one structural seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint (i.e., the rapid inflation of the inflatable chamber), when the structural seam is bonded with the adhesive.

5 It is desirable for the structural seam to have a lap shear geometry formed by two sheet edges overlapping each other so as to form overlapping sheet portions. The adhesive is disposed between the overlapping portions so as to bond the seam.

The adhesive, used according to the present invention, can be an adhesive selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, 10 ethylene/acrylic acid adhesives, polyurethane adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, polyolefin rubber adhesives, epoxy/polyolefin adhesives, polyamide adhesives, polyurea adhesives and combinations thereof, where the adhesive is formulated and prepared such that at least one structural seam bonded with the adhesive is capable of withstanding 15 inflation forces resulting from deployment of the inflatable restraint.

The adhesive, used according to the present invention, can be at least one silicone pressure-sensitive adhesive comprising a silicone base polymer and a silicate (e.g., MQ) resin, where the silicone base polymer comprises condensation curable functional groups, and the silicate resin comprises condensation curable functional 20 groups. The at least one silicone pressure-sensitive adhesive can be a condensation cured pressure-sensitive adhesive and/or a peroxide cured pressure-sensitive adhesive, where the condensation cure pressure-sensitive adhesive further comprises a condensation curing agent and the peroxide cure pressure-sensitive adhesive further comprises a peroxide cross-linking agent. The condensation curing 25 agent can be, for example, a condensation catalyst, a cross-linking agent, and/or a multifunctional cross-linking agent (e.g., an aminosilane) which serves as both catalyst and cross-linker. It can be desirable for the silicone base polymer and the silicate resin to be pre-condensed together prior to the at least one silicone pressure-sensitive adhesive being applied and fully condensation cured. Pre- 30 condensation of the pressure-sensitive adhesive can improve the shear strength and performance of the adhesive.

The adhesive, used according to the present invention, can be at least one addition-cure or hydrosilation cure silicone adhesive comprising an alkenyl functional silicone base polymer, a hydride functional cross-linking or chain extending agent (e.g., SiH), and a hydrosilation catalyst. The silicone base polymer has unsaturated (e.g., vinyl, propenyl, higher alkenyl, etc.) groups at its ends. It may be desirable for a reinforcing agent to be included such as, for example, a silica, quartz, and/or MQ resin containing alkenyl or SiH functional groups. The hydrosilation catalyst is typically a noble metal catalyst such as, for example, Pt and Rh. The at least one addition-cure silicone adhesive can be an addition-cure silicone pressure-sensitive adhesive or a room temperature vulcanizing adhesive.

The adhesive, used according to the present invention, can be at least one free radical-cure silicone pressure-sensitive adhesive comprising an ethylenically unsaturated silicone base polymer, and a silicate resin (e.g., MQ resin). The silicone base polymer has ethylenic unsaturation (e.g., acrylate, methacrylate, etc.) at its ends. The silicate resin is in sufficient quantity to provide the desired tack to the adhesive. It is desirable for a free radical catalyst to be included for initiating free radical polymerization, when the adhesive is to be thermal or thermal or radiation (e.g., UV or photo) cured. Optionally, a small percentage of a free radically polymerizable vinyl monomer can be included. In addition, a free radically polymerizable cross-linking agent may also be included.

The adhesive, used according to the present invention, can be at least one silicone adhesive comprising a non-curable tackified polydiorganosiloxane polyurea segmented copolymer. This at least one silicone adhesive can be selected from the group consisting of a pressure-sensitive adhesive (PSA), a heat activated pressure-sensitive adhesive (activated with heat and pressure), a non-tacky heat activated (e.g., hot-melt) adhesive and a combination thereof.

The adhesive, used according to the present invention, can be at least one silicone adhesive comprising a curable tackified polydiorganosiloxane oligourea segmented copolymer. This at least one silicone adhesive can be selected from the group consisting of a pressure-sensitive adhesive, a heat activated pressure-sensitive adhesive, a non-tacky heat activated adhesive and a combination thereof. This at

least one silicone adhesive can also be selected from the group consisting of a free-radical cure adhesive, a moisture cure adhesive and a combination thereof.

The adhesive, used according to the present invention, can be at least one moisture-cure room temperature vulcanizing silicone adhesive. This at least one  
5 silicone adhesive can be a neutral-cure room temperature vulcanizing adhesive.

In another aspect of the present invention, an inflatable protective device is provided which comprises a housing; an inflation device attached to the housing; and an inflatable restraint. The inflatable restraint comprises an inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive  
10 so as to have a lap-shear geometry. The adhesive is selected such that the at least one structural seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint, when the structural seam is bonded with the adhesive tape.

In a further aspect of the present invention, a method is provided for making  
15 an adhesive bonded inflatable restraint. The method comprises the steps of: providing an adhesive and at least one sheet of a material suitable for use in an inflatable restraint, with the sheet having two edges; overlapping the two edges of the sheet so as to form a seam having a lap shear geometry and to form at least part of an inflatable chamber; disposing the adhesive between the overlapping edges of  
20 the sheet; and activating the adhesive (by pressure and/or heat) so as to bond the overlapping edges together, wherein the adhesive is selected such that the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint, when the overlapping edges are bonded with the adhesive.

It can be desirable for the adhesive being provided to be a curable adhesive.  
25 In which case, the method includes the step of curing the adhesive after the step of activating the adhesive. The resulting seam will then, at least, be capable of withstanding inflation forces resulting from deployment of the inflatable restraint, after the adhesive is substantially cured. With at least two sheets of a material, suitable for use in an inflatable restraint, being provided, each sheet can provide one  
30 of the edges used to form the seam.

It can be desirable for the step of disposing the adhesive between the overlapping edges of the sheet to include bonding the adhesive along at least one of the edges before the step of overlapping the two edges of the sheet.

5 The present invention also relates to an improved inflatable restraint in which at least one structural seam, and optionally other structural and nonstructural seams, as well as other portions of the restraint, are adhesive bonded or reinforced with an adhesive tape.

10 Accordingly, in an additional aspect of the present invention, an inflatable restraint is provided which comprises an inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive tape. The adhesive tape is selected such that each structural seam bonded with the adhesive tape is capable of withstanding inflation forces resulting from the deployment of the inflatable restraint (i.e., the rapid inflation of the inflatable chamber).

15 The adhesive tape can comprise a backing having two major surfaces or sides and an adhesive on one major surface. In addition to the adhesive, the backing is selected such that each structural seam bonded with the adhesive tape is capable of withstanding inflation forces resulting from the deployment of the inflatable restraint. The backed adhesive tape can be used in bonding a structural seam having a butt joint geometry.

20 The backing of the tape can be made from any suitable coated or uncoated (e.g., with silicone) materials which pass deployment and durability testing as required for inflatable restraints, including suitable woven nylon fabrics, woven polyester fabrics, Kevlar®, Spectra®, films, nonwovens, including nonwoven fabrics, laminates of films, yarns and/or fibers, and the like.

25 The adhesive tape can, alternatively, be an adhesive transfer tape comprising one or more adhesive layers without a backing. It is desirable for such an adhesive tape to be self-supportive, without a support backing, when used to bond a structural seam of the inflatable restraint. Such an adhesive tape can be used in bonding overlapping portions of a structural seam having an overlapping or lap  
30 shear geometry. The transfer tape can also be a double sided adhesive tape, with adhesive on both sides of a reinforcement backing.

It is desirable for the adhesive for the tape to be a hot melt-type adhesive. The adhesive may also be a pressure sensitive-type adhesive. In addition, the adhesive may exhibit a combination of the characteristics of a hot melt-type adhesive and a pressure sensitive-type adhesive. That is, the adhesive may need to have both heat and pressure applied in order to be sufficiently activated. It has also been found desirable for the adhesive to comprise a silicone adhesive. It has been found more desirable for the adhesive to comprise a silicone adhesive containing a silicone-urea segmented copolymer and even more desirable for a silicate resin (e.g., an MQ resin) to be included with the silicone-urea segmented copolymer. It is believed that other adhesives which provide the required performance, durability and processability could also be used to make an adhesive tape according to the present invention. Other adhesives may include block co-polymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, polyurethane adhesives, polyester adhesives, polyamide adhesives and the like.

The inflatable chamber can include a retaining ring assembly. The retaining ring assembly comprises one or more retaining rings bonded about the periphery of an opening (e.g., a vent hole, an inflator hole, etc.) in the inflatable chamber. The retaining ring assembly can comprise one or more retaining rings bonded about the periphery of such an opening on an inner surface of the inflatable chamber, on an outer surface of the inflatable chamber, or on both the inner and outer surfaces. One or more adhesive layers are used to so bond each retaining ring. Each adhesive layer, with or without the corresponding retaining ring, can be an adhesive tape of the type used to bond a structural seam according to the present invention. Thus, the retaining ring and the adhesive layer can form a backed adhesive tape. It is believed that adhesives, other than those used in the present adhesive tape (e.g., lower strength adhesives), can also be used to successfully bond such retaining rings.

The inflatable restraint can also include a tether having each of two opposite ends bonded to one of two opposing inner surfaces of the inflatable chamber. Each end of the tether is bonded to one of the opposing inner surfaces of the inflatable chamber with an adhesive layer so that the adhesive layer is subjected to



substantially tensile or pluck loading, not peel loading, during the inflation of the inflatable chamber, as the inflatable restraint is deployed. The adhesive layer is selected so as to withstand the inflation forces resulting from the deployment of the inflatable restraint and so as to maintain the bond between the tether and the  
5 opposing inner surfaces. The tether has a length that limits the separation of the opposing inner surfaces during the inflation of the inflatable chamber.

In another aspect of the present invention, the above described adhesive tape is provided for bonding a structural seam of an inflatable restraint, the tape comprising at least one adhesive layer selected such that when used to bond a  
10 structural seam of an inflatable restraint, the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint.

In an additional aspect of the present invention, a method is provided for making the inflatable restraint described above. The method comprises the steps of: providing at least one sheet of a material suitable for making an inflatable restraint,  
15 with the at least one sheet having two edges, and also providing an adhesive tape; forming the at least one sheet so as to define an inflatable chamber having at least one structural seam formed by the two edges; and bonding a substantial portion of the at least one structural seam with the adhesive tape.

When the adhesive tape being provided is a backed adhesive tape, the  
20 forming step includes forming the at least one sheet so that the at least one structural seam has a butt joint geometry formed by the two edges, and the bonding step includes applying the backed adhesive tape so as to overlap the edges and bond the structural seam. When the adhesive tape being provided is an adhesive transfer tape, the forming step includes forming the at least one sheet so that the at least one  
25 structural seam has a lap shear geometry formed by the two edges overlapping each other so as to form overlapping portions of the at least one sheet, and the bonding step includes disposing the adhesive tape between the overlapping portions so as to bond the structural seam.

One of the advantages of the restraints of the present invention is that the  
30 seams may be adhesively bonded without the need for expensive adhesive-coated fabrics.

Another advantage of the restraints of the present invention is that adhesively-bonded restraints of the present invention may be manufactured at a lower cost, using less labor than sewn restraints.

Another advantage of the restraints of the present invention is that  
5 adhesively-bonded seams avoid stress concentrations in the fabric at the seams and thereby avoid the problem of combing.

Another advantage of the restraints of the present invention is that lighter weight fabrics may be used to construct the inflatable chamber which saves weight and decreases packing volume of the restraint in its un-deployed state. Lighter  
10 weight fabrics can also provide a surface that is less abrasive when impacted by a person or object.

#### **Brief Description of the Drawings**

Fig. 1 is a front view of one embodiment of an inflatable restraint of the  
15 present invention.

Fig. 2 shows the two sheets used to make the inflatable restraint shown in Fig. 1.

Fig. 3a is a front view of a tube for use in another embodiment of an inflatable restraint of the present invention with an adhesively-bonded seam having a  
20 lap-shear geometry.

Fig. 3b is a sectional view of the seam of the inflatable restraint of Fig. 3a taken along lines 3b-3b and having an overlap shear geometry according to the present invention.

Fig. 4 is a sectional view of the seam of the inflatable restraint of Fig. 1  
25 taken along lines 4-4 and having an overlap shear geometry according to the present invention.

Fig. 5 is a partial cross-sectional view of a typical sewn seam.

Fig. 6 is a partially sectioned view of an inflatable protective device of the present invention.

30 Fig. 7 is a cross-sectional view of a retaining ring assembly for use on an inflatable restraint in accordance with the present invention.

Fig. 8 is a side view of a deployed inflatable restraint according to the present invention, partially broken away so as to reveal a fully extended tether therein.

Fig. 9 is an enlarged view of the circled area of Fig. 8.

5 Fig. 10 is a front view of another embodiment of an inflatable restraint of the present invention.

Fig. 11 is a front view of an additional embodiment of an inflatable restraint of the present invention.

10 Fig. 12 is a sectional view of a structural seam having a butt joint geometry according to the present invention.

Fig. 13 is a cross-sectional view of a structural seam of an inflatable restraint having a lap shear geometry bonded with a double-sided tape according to the present invention.

## 15 **Detailed Description**

Although the present invention is herein described in terms of specific embodiments, it will be readily apparent to those skilled in this art that various modifications, re-arrangements, re-formulations, and substitutions can be made without departing from the spirit of the invention. The scope of the present invention is thus  
20 only limited by the claims appended hereto.

The inflatable restraints of the present invention include an inflatable chamber made from at least one sheet of material (e.g., a fabric), suitable for use in the inflatable restraint, forming at least one structural seam, and have a substantial portion of at least one structural seam bonded with an adhesive or an adhesive tape.  
25 "Inflatable restraint" as used herein refers to any inflatable restraint device, including driver-side airbags, passenger airbags, side impact airbags, inflatable seat belt restraints, knee bolsters, head liner curtains, and the like. "Structural seam" as used herein refers to a seam in the inflatable restraint that is subjected to gas pressure or forces due to inflation of the inflatable chamber and which must maintain integrity  
30 to a predetermined pressure during the operation of the inflatable restraint for its intended purpose. Examples of non-structural seam applications of the present

adhesive or adhesive tape include attaching fabric or material to the inflatable chamber to reinforce a vent hole or an inflator hole and the like.

Generally, the inflatable chamber may be any shape and configuration that allows the use of an adhesive to bond together the inflatable chamber. It is desirable for the inflatable chamber to be of a shape which allows for the structural seams to have a lap-shear geometry or butt joint geometry. Having a "lap-shear geometry" means that the seams are overlapping and positioned so that during inflation of the inflatable chamber, the force applied to the seams is substantially lateral or shear force, rather than substantially a "peel" force. Having a "butt joint" geometry means that the edges of the material brought together to form the seam are not overlapping but substantially abutted (i.e., adjacent to one another) or joined edge-to-edge. In such a geometry, the bonded seam will also be subject substantially to shear forces, rather than substantially "peel" forces, when the inflatable restraint is deployed. A seam having lap-shear geometry is shown in Figs. 3a, 3b and 4 (described in detail below). A seam having a butt joint geometry is shown in Fig. 12. This is in contrast to typically sewn seams of known inflatable restraints which are configured such that "peel" or perpendicular force acts upon the seam during inflation of the restraint. A peel type seam is shown in Fig. 5 (described in detail below). Useful shapes include polygons, for example, octagons, squares, triangles, and the like; pyramids; circles; interlocking "baseball" shaped pieces and interlocking "dogbone" shaped pieces. Other useful shapes that can be adhesively bonded using lap-shear geometry seams includes those described in U.S. Patent Nos. 4,988,118; 5,454,594; and 5,482,317, all of which are incorporated in their entirety herein by reference.

The inflatable restraints of the present invention may be made of a single piece or sheet of material or of two or more sheets of material. An inflatable restraint of the present invention may generally be made from a single sheet of material by folding the material and forming edges and then bonding the respective edges with an adhesive in a lap-shear or butt joint geometry. An inflatable restraint of the present invention may also be made by adhesively bonding two or more sheets of material together at their respective edges. The inflatable restraints of the

present invention may also have additional adhesively-bonded seams which give the uninflated restraint a three-dimensional structure. For example, an inflatable restraint, adhesively bonded together according to the present invention, may be folded inwardly at a seam and then the folds are adhesively bonded together to form  
5 a seam which extends into the vertical plane of the inflatable chamber.

Generally, any fabric or material suitable for use in an inflatable restraint may be used to make the inflatable restraints of the present invention. Useful materials include sheets made from fabrics of nylon 6, nylon 6,6, Kevlar®, and polyester (DACRON®) yarns. It is desirable for the fabrics to be woven from such  
10 yarns having a denier of about 840 or less. It is more desirable for the fabric bonded according to the present invention to have a denier of about 630 or less. It is even more desirable for the fabric to have a denier of about 420 or less. By using adhesive bonding according to the present invention, it is believed that the inflatable chamber can even be made from relatively lightweight fabrics (i.e., about 210 denier  
15 or less), compared to that typically used in the past. The useful fabrics may also have a balanced or unbalanced weave, that is, the fabric may be woven with fabrics having the same or a different denier and thread counts in the warp and filling directions.

The sheet materials of the present inflatable restraints may be coated or  
20 uncoated. Coatings are used to make the fabric less permeable to the inflation gas. Satisfactory results have been obtained with uncoated and silicone coated nylon fabrics. Other useful coatings may also include for example, rubber, polyurethane, and neoprene. Commercially available fabrics include silicone coated nylon 6,6 Fabric Style Nos. 64318 and 64362, available from Precision Fabrics Group Inc.,  
25 Greensboro, North Carolina; uncoated nylon 6,6 (630 denier), available from Highland Industries Inc., Greensboro, NC; and silicone coated or uncoated nylon woven fabric (420 denier) from Milliken & Co., Spartanburg, South Carolina.

The adhesive tape used to bond structural seams in the inflatable restraints of the present invention may be any adhesive tape that is compatible with the  
30 materials used in the inflatable restraint and capable of withstanding the inflation forces caused by deployment of the inflatable restraint. In other words, the

adhesive tape should exhibit sufficient shear-holding power such that the structural integrity of the seam and the restraint as a whole is maintained during the unused life of the inflatable restraint, as well as during deployment. Generally, the strength of the tape-bonded structural seams of the present invention is dependent on the

5 type of fabric used for the inflatable chamber; the backing, if present, and the adhesive used in the adhesive tape; and the design of the inflatable restraint. It is desirable for an inflatable restraint of the present invention to have tape-bonded structural seams that withstand an internal inflation pressure of from at least about 2 psi (14 kPa) to about 60 psi (414 kPa), or more depending on the requirements of

10 the particular inflatable restraint. For at least some inflatable restraint applications, it is believed desirable for a tape-bonded structural seam, according to the present invention, to have a shear strength at room temperature of at least about 50 psi (345 kPa) and, more desirably, of at least about 75 psi (517 kPa). It is desirable for a tape-bonded structural seam, according to the present invention, to have a shear

15 strength at room temperature of at least about 100 psi (690 kPa) and, more desirably, at least about 120 psi (827 kPa).

Any coated or uncoated (e.g., with silicone) material that meets deployment and durability requirements required for inflatable restraints may be useful as a backing in the present adhesive tape. Such materials may include, but are not

20 limited to, suitable woven nylon fabrics, woven polyester fabrics, Kevlar®, Spectra®, films, nonwovens, including nonwoven fabrics, laminates of films, yarns and/or fibers, and the like. It is desirable for the backing to be made of materials like those used to make the sheet(s) for the inflatable chamber. It has been found desirable for the backing to be an uncoated woven nylon fabric. Though, the fabric

25 backing can have a coating (e.g., silicone) on one or both sides, with the adhesive coated onto a coated side or an uncoated side.

The adhesive used to bond structural seams in the inflatable restraints of the present invention may be any adhesive that is compatible with the materials used in the inflatable restraint and capable of withstanding the inflation forces caused by

30 deployment of the inflatable restraint. In other words, the adhesive should exhibit sufficient shear-holding power such that the structural integrity of the seam and the

restraint as a whole is maintained during the unused life of the inflatable restraint, as well as during deployment. The type and amount of adhesive used is largely dependent on the type of fabric and/or coating used to make the inflatable restraint. For example, it is desirable to use a silicone adhesive for bonding a silicone coated fabric of nylon 6,6. A silicone adhesive can also be used to bond an uncoated fabric of nylon 6,6.

Suitable adhesives provide a high level of bonding to low energy surfaces and are flexible through a temperature range of from about -30°C to 90°C. Such adhesives also do not adversely affect the fabric or fabric coating, are stable for at least 10 years, and do not outgas or "fog" excessively. Silicone adhesives can provide long-term durability and are useful over a wide range of temperature, humidity and environmental conditions, and can be used effectively to bond to surfaces coated with silicone or other high and low surface energy coatings, such as coatings found on the sheet materials currently used to make inflatable restraints.

For the adhesive tapes, any adhesive that imparts the desired shear holding power to the tape and that possesses properties that allow it to be applied to a backing, if applicable, so as to produce a usable adhesive tape for inflatable restraint applications may be employed in the present adhesive tape. It is desirable for the adhesive used in the present adhesive tape to be a hot-melt or pressure-sensitive adhesive (PSA). It is also desirable for the class of adhesives used in the present adhesive tape to be silicone adhesives. Silicone adhesives can provide long-term durability and are useful over a wide range of temperature, humidity and environmental conditions, and can be used effectively to bond to surfaces coated with silicone or other high and low surface energy coatings, such as coatings found on the sheet materials currently used to make inflatable restraints.

A desirable silicone adhesive that has been used to bond together inflatable restraints, with satisfactory results, is a silicone pressure-sensitive adhesive, commercially available under the tradename SILGRIP® PSA529 from GE Silicones, Waterford, NY. This adhesive was fully cured or cross-linked after the adhesive was applied and the seam(s) of the inflatable restraint formed. The cross-linking agent successfully used with the GE PSA 529 adhesive was the aminosilane

catalyst/cross-linking agent, commercially available from OSi Specialties, Inc. of Endicott, New York, under the product designation OSi A-1100 (aminopropyltriethoxysilane). This catalyst/cross-linking agent is also commercially available from GE Silicones, Waterford, NY under the product designation SRC18.

5           General Electric provides its PSA529 as a 55 wt% solids solution of silanol terminated linear polydimethylsiloxane gum and a silanol functional MQ resin (consists of M  $[(CH_3)_3SiO_{1/2}]$  and Q  $[SiO_{4/2}]$  structural units) that has been slightly condensed to increase the cohesive strength of the adhesive. The resin to gum ratio in the GE PSA529 is believed to be about 62/38 (MQ resin/gum) by weight. The  
10   GE PSA529 can be cured by either peroxide-cure (free radical) or condensation-cure. The recommended condensation cure formulation is 100 parts by weight (pt) of the PSA529 with 3.3 pt of the GE catalyst SRC18 (aminopropyltriethoxysilane). Satisfactory results have been obtained employing 3 pt of SRC18 per 100 pt PSA529.

15           Because the SRC18 catalyst is an active form of condensation catalyst, a catalyzed solution of the PSA529 will continue to advance in cure, as evidenced by increased viscosity, until gelled. Advancement of cure may be retarded significantly by diluting the adhesive to a lower concentration with solvent. A catalyzed GE PSA529 adhesive sample, at 30% solids, may have a useful bathlife in a closed  
20   container of up to 3 months.

          It is believed that a wide variety of silicone adhesive compositions are useful in constructing an inflatable restraint of the present invention. Such compositions cover a wide range of moduli, including those compositions of quite low modulus that exhibit pressure-sensitive tack, compositions of intermediate modulus that  
25   exhibit pressure-sensitive tack at elevated temperature, and the high modulus silicone rubber adhesives that possess no pressure-sensitive tack. Examples of other adhesives that may be useful in adhesively bonding inflatable restraints are discussed below.

          Silicone pressure-sensitive adhesives (PSAs), like those disclosed herein,  
30   generally comprise a high molecular weight linear and/or branched polydiorganosiloxane polymer that contains SiOH functionality and an SiOH



functional copolymeric silicone resin (also referred to as a silicate resin) comprising triorganosiloxy units and  $\text{SiO}_{4/2}$  units. Examples of silicate resins include MQ resins, MQD resins, and MQT resins. The SiOH groups on the copolymeric resin and the polydiorganosiloxane polymer can be reacted together via condensation  
5 reaction, as taught in U.S. Patents Nos. 2,738,721; 2,814,601; 2,857,356; 3,528,940; 4,309,520; 5,281,455; and great Britain Patent No. 998,232, which are incorporated in their entirety herein by reference, to provide a solvent soluble silicone PSA having improved cohesive strength. Such a composition may be employed without further cure. It is desirable for these compositions to be  
10 subsequently cured to further increase cohesive strength.

In the uncured state the tack level of silicone PSAs is primarily controlled by the amount of silicate resin (e.g., MQ resin) employed. Adhesives ranging from those exhibiting high tack to those possessing no tack at room temperature can be obtained by appropriately selecting the silicate resin concentration. Generally, for  
15 such silicone pressure sensitive adhesives exhibiting a relatively high tack, increases in the silicate resin concentration decreases the tack of the adhesive. Depending on the particular MQ resin used (e.g., its molecular weight, M:Q ratio, etc.), it can be desirable for the MQ resin concentration to be in the range of from about 50 wt% to about 70 wt%. It can also be desirable for the MQ resin concentration to be in  
20 the range of from about 60 wt% to about 65 wt%. At MQ resin concentrations of greater than about 75-80 wt%, the adhesive can become too glassy and fragile for use in bonding an inflatable restraint. A high tack and a low tack silicone PSA can be blended to obtain properties that are intermediate of the two adhesives. U.S. Patent No. 5,096,981, which is incorporated in its entirety herein by reference,  
25 describes the blending of such adhesives. In the cured state the tack of silicone PSAs is primarily controlled by the cross-link density of the composition, with increased cross-link density resulting in decreased tack and peel, and increased cohesive strength.

In general, silicone PSAs of this type may be cured by condensation-cure,  
30 peroxide cure, or a combination of the two. Condensation cure may be effected by use of several different types of catalysts. Commonly employed catalysts for such a

reaction include amines, aminosilane derivatives, titanates, and carboxylic salts of lead, tin, and zinc. Also believed useful are the UV triggered condensation catalysts described in U.S. Patent Application Serial No. 08/815,029, filed March 14, 1997, entitled CURE-ON-DEMAND MOISTURE-CURABLE COMPOSITIONS

5 HAVING REACTIVE SILANE FUNCTIONALITY, assigned to the assignee of the present application, and incorporated in its entirety herein by reference. A condensation catalyst may be employed alone or in combination with a cross-linking agent. Common cross-linking agents suitable for use include multifunctional silanes or siloxanes having moisture curable groups, e.g., alkoxy, alkenoxy, alkamido, 10 acylamido, or dialkylketoximino. Some molecules can serve as both catalyst and cross-linking agent as is the case with aminopropyltriethoxysilane and N-(2-aminoethyl)-3-aminopropyltrimethoxysilane.

With a peroxide cure, a diaryl peroxide cross-linking compound is typically added to the adhesive solution. The adhesive is then applied to a backing and 15 heated moderately to remove solvent. This step is followed by further heating to elevated temperatures to activate the cross-linking agent as disclosed in U.S. Patent No. 4,039,707, which is incorporated in its entirety herein by reference. At elevated temperatures the peroxide compound decomposes to form free radicals that abstract protons from organic substituents along the polydiorganosiloxane backbone. These 20 resultant radicals then combine to form rigid cross-links between the polydiorganosiloxane chains. These adhesive compositions can also be cured using two component room temperature free radical curatives consisting of a cross-linking catalyst and an accelerator. Common cross-linking catalysts useful in this two component curative can include peroxides and hydroperoxides such as 25 dibenzoyl peroxide, t-butyl hydroperoxide, and cumene hydroperoxide, which are not active at room temperature. The accelerator component of the curative includes the condensation reaction product of a primary or secondary amine and an aldehyde. Common accelerators of this type are butyraldehyde-aniline and butyraldehyde-butylamine condensation products such as, for example, that sold by 30 E.I. duPont de Nemours & Co. as Accelerator 808™ and Accelerator 833™. This catalyst system may be employed to prepare a two-part free radically curable

adhesive system where the adhesive system is divided into two parts and the cross-linking catalyst is added to one part and the accelerator is added to the other part. Upon mixing, this two component system typically cures at room temperature. Alternatively, the cross-linking catalyst can be incorporated in the adhesive and the accelerator can be applied to a substrate such that when the free radically curable adhesive, containing the cross-linking catalyst, contacts the "primed" substrate surface, cure proceeds immediately at room temperature.

Silicone PSAs prepared by addition-cure chemistry generally comprise polydiorganosiloxanes having alkenyl groups, MQ resin having silicone-bonded hydrogen, silicone bonded alkenyl, or silanol groups, Pt or other noble metal hydrosilation catalyst to effect the curing of the silicone PSA, and optionally a cross-linking or chain extending agent and hydrosilation inhibitor to extend bath life. Examples of such compositions are found in U.S. Patents Nos. 3,527,842; 3,983,298; 4,774,297; European Patent Publication Nos. 355,991; and 393,426, and Japanese Kokai HEI 2-58587, which are incorporated in their entirety herein by reference. Advantages of the use of addition-cure silicone PSAs include reduced solution viscosity as compared to silicone PSAs prepared via condensation chemistry, higher solids content, stable viscosity with respect to time, and lower temperature cure. While silicone PSAs prepared by condensation chemistry are typically delivered from solvent, addition-cure silicone PSAs can be prepared in a solventless format as shown in U.S. Patents Nos. 5,169,727 and 5,248,739, which are incorporated in their entirety herein by reference. Curing is typically effected by thermally activating the hydrosilation catalyst, however hydrosilation catalysts activated by actinic radiation may also be useful in these compositions as described in U.S. Patents Nos. 4,530,879 and 4,510,094, which are incorporated in their entirety herein by reference.

Another class of silicone PSAs which may be useful in the present invention are those cured by free radical polymerization of unsaturated groups. Such compositions generally comprise a polydiorganosiloxane polymer bearing ethylenically unsaturated groups, sufficient silicate resin (e.g., MQ resin) to tackify the composition for the intended purpose, and optionally free radically

polymerizable vinyl monomer and free radical initiator. Such compositions are described in U.S. Patents Nos. 5,514,730; 5,264,278; and 5,091,483, which are incorporated in their entirety herein by reference.

5 Tackified polydiorganosiloxane polyurea segmented copolymers represent another adhesive type having utility in the instant invention. In general, these compositions each comprise a polydiorganosiloxane polyurea segmented copolymer and a silicate (e.g., MQ) tackifying resin and provide adhesives ranging in modulus from PSAs, to heat activated PSAs, to non tacky high strength heat activated or hot melt adhesives. Examples of such compositions are described in the U.S. Patent  
10 No. 5,461,134, which is incorporated in its entirety herein by reference. Examples of such compositions are also described in the PCT Patent Application No. PCT/US96/05852 (Publication No. WO96/35458) entitled TACKIFIED POLYDIORGANOSILOXANE POLYUREA SEGMENTED COPOLYMERS AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is  
15 assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference. Copolymers that can be used to make such silicone adhesives are disclosed in the PCT Patent Application No. PCT/US96/05869 (Publication No. WO96/34029) entitled POLYDIORGANOSILOXANE POLYUREA SEGMENTED COPOLYMERS  
20 AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosures of which is incorporated in their entirety herein by reference. Such compositions require no cure and may be delivered to the area to be bonded in a number of ways including from solvent, from an extrusion die at elevated temperature, or in tape form. If the  
25 tape product is a PSA it may be applied to the bond area as received. Alternatively, if the tape product is a higher modulus tack free composition (heat activated or hot-melt adhesive), the tape may be applied to the bond area and activated with heat and pressure to create the bond.

Another class of silicone PSAs useful in constructing articles of the present  
30 invention are those compositions comprising a curable polydiorganosiloxane oligourea segmented copolymer tackified with MQ resin. Such compositions can be

formulated to be cured under free radical or moisture cure conditions and provide adhesives ranging in modulus from PSAs, to heat activated PSAs, to non tacky high strength adhesives. Examples of such compositions are described in the PCT Patent Application No. PCT/US96/05829 (WO96/34028) entitled TACKIFIED

5 POLYDIORGANOSILOXANE OLIGOUREA SEGMENTED COPOLYMERS AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference. Copolymers that can be used to make such silicone adhesives are disclosed in the PCT Patent Application No.

10 PCT/US96/05870 (WO96/34030) entitled POLYDIORGANOSILOXANE OLIGOUREA SEGMENTED COPOLYMERS AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference. Depending on the adhesive composition employed, the adhesive may be

15 delivered in a number of ways including from solvent, as a tape product, or in neat form at elevated temperature such as from an extrusion die. If the composition is free radically cured it may then be exposed to conditions appropriate to achieve cure, e.g., actinic radiation, thermal treatment, etc. depending on the initiation system, if any, employed.

20 Moisture curable room temperature vulcanizable (RTV) silicones are yet another useful class of adhesive-type material which may be used in accordance with the present invention. Upon exposure to atmospheric moisture, RTV silicones undergo hydrolysis and condensation reactions to yield high strength silicone adhesives, sealants, and elastomers. Two basic cure chemistries are employed to

25 prepare RTV silicones adhesives, acetoxy-based cure systems and alkoxy-based cure systems. Acetoxy-based adhesives are described in U.S. Pat. Nos. 3,133,891 and 3,035,016; methoxy-based adhesives are described in U.S. Pat. No. 3,127,363, the disclosures of all of these patents are incorporated in their entirety herein by reference. Typical of the acetoxy-cure system would be an adhesive comprising an

30 SiOH terminated polydiorganosiloxane polymer, a multifunctional acetoxysilane cross-linker, such as methyltriacetoxysilane, and optionally a condensation catalyst,

often of the tin (IV) type. Upon exposure to atmospheric moisture the cross-linker hydrolyzes, liberating acetic acid, reacts with the silanol functional polymer, and as condensation proceeds results in formation of the cross-linked adhesive network.

The alkoxy-based systems are very similar to the acetoxo-based systems, one principle difference being that alkoxy rather than acetoxo functional cross-linkers are employed, such as methyltrimethoxysilane. Methoxy-based cross-linkers and silanol functional polymers do not spontaneously react with atmospheric moisture under pH-neutral conditions, and therefore, a catalyst is required to facilitate cure. Adhesives are typically filled to both control viscosity of the uncured composition and reinforce the cured adhesive. Silicone RTV adhesives commonly employ adhesion promoters such as trialkoxy- or dialkoxy-substituted silanes, e.g., aminopropyltrimethoxysilane, cyanoethyltriethoxysilane, and glycidoxypolypropyltrimethoxysilane, to enhance adhesion to difficult to bond substrates.

Silicone adhesives prepared by addition-cure chemistry generally comprise polydiorganosiloxanes having alkenyl groups, a silicon-hydride functional cross-linking agent, Pt or other noble metal hydrosilation catalyst to effect curing of the adhesive, and optionally a silicon-hydride chain extending agent; a silicate (e.g., MQ) resin having silicon-bonded hydrogen, silicon-bonded alkenyl, or silanol groups; hydrosilation inhibitor; filler; and/or adhesion promoter. Such products may be delivered as one-part compositions or two-part compositions, and may be provided in the form of pourable fluid, thick paste, or semi-solid. Adhesion promoters, e.g., epoxy- and alkenyl-substituted silanes, such as vinyltriethoxysilane, vinyltriacetoxysilane, and glycidoxypolypropyltrimethoxysilane, as well as siloxane oligomers bearing both unsaturation and silanol functionality on the same molecule, are used in such compositions to enhance adhesion to difficult to bond substrates. Cure is typically obtained by exposing the adhesive to temperatures in the range of 80°C to 150°C for an appropriate length of time, although room temperature cure addition-cure adhesives are known. An example of a two-part thermally activated addition-cure adhesive is found in US Patent No. 4,087,585, which is incorporated in its entirety herein by reference.

Other suitable adhesives may also include block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives (such as, for example, that disclosed in U.S. Patent No. 5,308,887 which is incorporated in its entirety herein by reference), ethylene acrylic acid adhesives, polyurethane  
5 adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, epoxy/polyolefin adhesives, flexible epoxy adhesives, polyamide adhesives, polyurea adhesives and the like.

Adhesives useful in constructing articles of the present invention may optionally contain pigments, dyes, or colorant agents for the purpose of coloring the  
10 adhesive. The type and amount of colorant agent should be chosen so as not to compromise the function of the adhesive. Depending on the relative translucency or opacity of the inflatable restraint material, a colored adhesive can help determine the placement and uniformity of adhesive in the bond line of an inflatable restraint of the present invention. In addition to conventional coloring agents, fluorescent  
15 compounds, dyes, or pigments as taught in US Patent No. 4,922,113, which is incorporated herein by reference, and the references found therein, may be added to the adhesive to assist in determining uniformity, registry, and defects in the adhesive and bond lines created therefrom. To observe either the adhesive or a bond line formed from, for example, a fluorescent agent containing adhesive, the area of  
20 interest is irradiated with a wavelength of light appropriate to excite the fluorescent agent and the resulting fluorescent emission is monitored. Suitable monitoring equipment and techniques can encompass a simple visualization of the irradiated area of interest or may involve electronic devices such as photodiodes or phototubes to more precisely measure the fluorescent emission. One of ordinary  
25 skill in the art could readily employ any of the above visualization equipment to monitor adhesive and/or adhesive/bond lines.

Generally, the strength of the adhesively-bonded structural seams of the present invention is dependent on the fabric type, the adhesive, the seam geometry and the design of the inflatable restraint. It is desirable for an inflatable restraint of  
30 the present invention to have adhesively-bonded structural seams that withstand an internal inflation pressure of from at least about 2 psi (13.8 kPa) to about 60 psi

(413.7 kPa) ), or more depending on the requirements of the particular inflatable restraint. It is believed desirable for an adhesive bonded structural seam, according to the present invention, to have a shear strength at room temperature of at least about 50 psi (345 kPa) and, more desirably, at least about 75 psi (517 kPa). It is  
5 desirable for an adhesive bonded structural seam, according to the present invention, to have a shear strength at room temperature of at least about 100 psi (690 kPa) and, more desirably, at least about 120 psi (827 kPa).

Generally, the adhesive is applied to at least partially coat the fabric, forming one or both sides of the seam, to a thickness that will result in a sufficiently strong  
10 bond. It is desirable for the thickness of the applied adhesive to be in the range of from about 0.5 to about 15 mils (0.005 to 0.038 cm) and more desirable from about 0.5 to about 10 mils (0.005 to 0.025 cm). The amount of overlap of the adhesively-bonded seams having lap-shear geometry is that amount which is sufficient to withstand the inflatable restraint inflation pressures without failing. It is believed  
15 that the amount of overlap in an adhesive bonded lap-shear geometry seam of the present invention can be as low as about 1/8 inch (0.38 cm) to as wide as desired. The width of the overlap may also vary along the length of the seam. The amount of overlap (i.e., seam width) should not be so excessive as to limit or prohibit sufficient flexibility of the inflatable restraint. It may be desirable for the lap-shear  
20 seams of the present invention to have an overlap width in the range of about 1/8 inch (0.38 cm) to about 2 inches (5.08 cm). It can be more desirable for the lap-shear seams to have an overlap width in the range of from about 0.5 inch (1.27 cm) to about 1 inch (2.54 cm).

An example of an adhesive bonded inflatable restraint of the present  
25 invention is shown in Fig. 1. The inflatable restraint 10 comprises two adhesively-bonded sheets 14, 16 (see Fig. 2) made from, for example, a nylon 6,6 fabric which when adhesively bonded together at respective edges (see Fig. 4), forms an inflatable chamber 12. As shown more particularly in Fig. 2, sheets 14, 16 have a generally octagonal shape, with sheet 14 having a smaller diameter. The sheets 14,  
30 16 are bonded with an adhesive 17 to form inflatable chamber 12 by means of seams 20 having lap-shear geometry as shown more particularly in Fig. 4. The



seams 20 are made from folded edge sections or flaps 22 of sheet 16 which are folded onto and overlap the edge 24 of sheet 14. Sheet 16 has a plurality of cuts or slices 26 which define flaps 22. Sheet 16 also has a centrally located inflator hole 11 with corresponding mounting holes 13. Chamber 12 may also have vent  
5 holes 15.

Fig. 3a illustrates an adhesively bonded tube 28 which forms part of an inflatable seat belt type inflatable restraint 30. The tube 28 is formed by a rectangular sheet 32, of a suitable material, which has two opposite edges 31 and 33 joined to form a structural seam 34 along the length of the tube 28. The structural  
10 seam 34 is bonded with one or more layers of an adhesive 36 according to the present invention so as to form the lap shear joint configuration shown in Fig. 3b.

If coated fabrics are used, it can be desirable for a coated fabric surface to be adhesive bonded to an uncoated fabric surface. For example, with the tubular inflatable restraint 30 of Figs. 3a and 3b, it is often desirable for the inside surface of  
15 the tube 28 (i.e., the fabric) to be coated with silicone, while the outside surface of the tube 28 is left uncoated. Thus, such a tube 28 will have a coated and uncoated fabric surface bonded with an adhesive.

Referring to Fig. 6, the present invention includes an inflatable protective device 30 which comprises an adhesive bonded inflatable restraint 10 of any desired  
20 configuration within a housing 40 which is attached to an inflation device 50. The inflation device 50 may be chosen from any of the inflation devices known to those skilled in the art. Specific examples of useful inflation devices and housings are described in U.S. Patent No. 4,828,286, incorporated by reference herein. Other inflation devices and housings that are compatible with the inflatable restraints of  
25 the present invention may be selected by those skilled in the art without undue experimentation.

Referring to Fig. 7, a retaining ring assembly 52, in accordance with the present invention, can comprise one or more retaining rings 54 bonded about the periphery of an opening 56 (e.g., a vent hole, an inflator hole, etc.) in an inflatable  
30 chamber defined by at least one sheet 60 of a fabric or other material suitable for an inflatable restraint. The retaining ring assembly 52 can comprise one or more

retaining rings 54 bonded about the periphery of such an opening 56 on an inner surface 62 of the inflatable chamber 58, on an outer surface 64 of the inflatable chamber 58, or on both the inner and outer surfaces 62 and 64, as shown. One or more of an adhesive layer 66 is used to so bond each retaining ring 54. Each  
5 adhesive layer 66, without the corresponding retaining ring 54, can be in the form of an adhesive transfer tape. Alternatively, each retaining ring 54 and the corresponding adhesive layer(s) 66 can form a backed adhesive tape ring 68.

Referring to Figs. 8 and 9, an inflatable restraint 82 can include a tether 84 having a cord or ribbon 85 with each of two opposite ends 86 and 88 bonded to one  
10 of two opposing inner surfaces 90 and 92, respectively, of the inflatable chamber 94 of the restraint 82. Each end 86 and 88 of the tether 84 is bonded to its corresponding inner surface 90 and 92 of the inflatable chamber 94 with an adhesive layer 96 so that the adhesive layer 96 is subjected to substantially tensile loading, not peel loading, during the inflation of the inflatable chamber 94, as the inflatable  
15 restraint 82 is deployed. At least substantial, if not pure, tensile loading forces can be obtained by securing or otherwise forming a patch 98 of suitable material (e.g., like that used to make the tether cord or ribbon 85, the inflatable chamber 94, etc.) on each end 86 and 88. Each patch 98 can be an integral part of the cord or ribbon 85 or secured to the ends 86 and 88 such as, for example, by sewing,  
20 stapling, adhesive bonding or a combination thereof. To obtain such tensile loading on the bond made by adhesive layers 96, each end 86 and 88 should be centrally positioned on its corresponding patch 98. In addition, each patch 98 should be of sufficient surface area to provide the adhesive bonding strength required. The adhesive layer 96 is selected so as to withstand the inflation forces resulting from  
25 the deployment of the inflatable restraint 82 and so as to maintain the bond between the tether 84 and the opposing inner surfaces 90 and 92. The adhesive layer 96 can be an adhesive transfer tape according to the present invention. The tether 84 has a length that limits the separation of the opposing inner surfaces 90 and 92 during the inflation of the inflatable chamber 94, as desired.

30 It is believed that adhesives, other than that used to bond structural seams, can also be used to successfully bond such retaining rings 54, depending on the

structural reinforcement requirements of the retaining ring assembly 52. In addition, each retaining ring 54 can be made of the same material as the sheet 60, or tailored to meet the structural requirements of the desired reinforcement. For example, a retaining ring of fabric coated with silicone or a ceramic based material  
5 may be required to function as a heat shield.

The adhesive tape may be made using known methods of making backed adhesive tape or adhesive transfer tape. The adhesive tape can be slit into rolls, cut into strips, or cut into shapes. When backed, the adhesive tape can be cut along the fabric warp or weft direction, or at any angle across the fabric. To make an  
10 inflatable restraint in accordance with the present invention, one or more sheets of a material suitable for use in an inflatable restraint are provided. The material is manipulated to form an inflatable chamber having at least one structural seam. The structural seam is formed by substantially abutting edges of the material to form a butt joint seam, or by overlapping the edges to form a lap shear seam. The tape as  
15 described herein is then applied to bond the seam by pressure or heat or both, depending on the adhesive used.

Referring to Fig. 10, a circular airbag type inflatable restraint 100 includes two circular sheets 112 and 114, made of a suitable fabric or other material, and a structural seam 116 at the perimeter thereof. The sheets 112 and 114 define the  
20 inflatable chamber portion of the restraint 100. The seam 116 is formed circumferentially around the entire periphery of the airbag 100 and has a butt joint geometry like that shown in Fig. 12 and is bonded using a backed adhesive tape 118, according to the present invention. The airbag 100 includes an inflator hole 120 and a vent hole 122. The inflator hole 120 is reinforced with a retaining  
25 ring assembly 124, like that shown in Fig. 7. The retaining ring assembly 124 is adapted, in a conventional manner, to receive a suitable inflator. The vent hole 122 is reinforced with another retaining ring assembly 126 which is the same or similar to the assembly 124.

Referring to Fig. 11, a square airbag type inflatable restraint 38 is  
30 constructed from one square sheet 40 of suitable material folded onto itself, at each corner, to create structural seams 42 on the diagonals. Each of the diagonal

seams 42 has a butt joint geometry like that shown in Fig. 12 and is bonded using a length of backed adhesive tape 44, according to the present invention. An inflator hole 46 is formed by cutting (e.g., by die cutting) an appropriate portion of each folded corner of the sheet 40. Like the above described circular airbag 100, the square airbag 38 includes a retaining ring assembly 48 for the inflator hole 46 and a retaining ring assembly 50 for a vent hole. The retaining ring assembly 48 can be applied so as to provide all of the reinforcement for each portion of the corners defining the inflator hole 46. That is, each tape 44 can be cut short so as not to cover the full length the corresponding seam 42 and to stop just short of reaching the assembly 48. Alternatively, each length of the tape 44 can be cut so as to bond the entire length of each seam 42. With this configuration, the retaining ring 48 can be positioned so as to overlap the corresponding end of each tape 44 and bond to each tape 44 and each folded corner of the sheet 40.

Fig. 12 illustrates an adhesively bonded structural seam 134 that is bonded using a backed adhesive tape 136 so as to form a butt joint configuration. The adhesive tape 136 includes a backing 135 and an adhesive layer 137 of suitable materials, according to the principles of the present invention. Alternatively, the edges 131 and 133 could be overlapped (i.e., one edge 131 or 133 is underneath the other) and the resulting overlapping seam bonded with the tape 136 such that the underlying edge 131 or 133 is not in contact with the tape 136.

Whether in the form of an adhesive transfer tape or a backed adhesive tape, it can be desirable for the adhesive layer to be mounted on a suitable release liner. Whether a release liner is used depends, at least in part, on the degree to which the adhesive bonds to itself (in the case of the adhesive transfer tape) or the degree to which the adhesive bonds to the exposed surface of the adhesive backing (in the case of the backed adhesive tape). It can also be desirable to use a release liner when the layer of adhesive forming the transfer tape is not self-supportive.

Each backed adhesive tape ring 68 and each adhesive transfer tape layer 66, as well as individual retaining rings 54, can be formed, for example, by being die cut to the shape desired. The use of a release liner can facilitate a die cutting-type forming operation. If the adhesive used is a hot melt-type and/or a pressure

sensitive-type, the adhesive tape can be bonded to the desired substrate (i.e., either a sheet or a retaining ring) with heat and/or pressure in a conventional manner.

Both heat and pressure can be applied when the adhesive exhibits both heat and pressure activated characteristics.

- 5           Referring to Fig. 13, a structural seam 70 in an inflatable restraint (e.g., like that shown in Fig. 3a) can be bonded in a lap shear geometry using an adhesive transfer tape 72, in accordance with the present invention. The seam 70 is formed by overlapping portions 74 and 76 of one or more sheets of a suitable material for an inflatable restraint. The tape 72 can be a double sided adhesive tape, as shown,
- 10       with one or more of an adhesive layer 78 on both sides of a reinforcement layer or backing 80. Each layer 78 is bonded to one of the overlapping portions 74 and 76. The backing 80 can be any suitable material which will not delaminate from the adhesive layers 78 and provides the required structural support for the adhesive layers 78. The adhesive transfer tape can, alternatively, comprise one or more
- 15       adhesive layers without a backing. It is desirable for such an adhesive tape to be self-supportive, without a support backing, when used to bond a structural seam of the inflatable restraint.

**Experimental****Test Procedures For Examples A & B****Lap-Shear Test**

Two 4 inch (10.2 cm) by 5 inch (12.7 cm) samples of the fabric to be tested were cut. The two fabric samples were adhesively bonded together with a 1 inch (2.54 cm) overlap. The adhesive was applied to the area(s) to be bonded in an amount to visually cover the area to be bonded. The bonded fabric samples were allowed to cure, and then were cut into three 1 inch (2.54 cm) by 5 inch (12.7 cm) strips. The bonded strips were tested for shear strength in a tensile testing machine (Instron™ Model No. 1122), with an initial jaw gap of 4 inches (10.2 cm), a jaw width of 1 inch (2.54 cm), a crosshead speed of 12 inch/min (30 cm/min), and a scale range of 200 lbf (889.6 N). The test was performed on three samples for each adhesive/fabric combination and the results were averaged.

**Peel Test (180° T-Peel)**

Two 4 inch (10.2 cm) by 5 inch (12.7 cm) samples of the fabric to be tested were cut. The two fabric samples were adhesively bonded together with a 4 inch (10.2 cm) overlap, with the edges parallel. The adhesive was applied to the area(s) to be bonded in an amount to visually cover the area to be bonded. After bonded fabric samples were allowed to cure, the samples were cut into three 1 inch (2.54 cm) by 5 inch (12.7 cm) strips. The bonded strips were tested for 180° peel strength in a tensile testing machine (Instron™ Model No. 1122) with an initial jaw gap of 1 inch (2.54 cm), a jaw width of 1 inch (2.54 cm), a crosshead speed of 12 inch/min (30 cm/min), and a full scale range of 20 lbf (89.0 N). The test was performed three times for each adhesive/fabric combination and the results were averaged.

**Fabric Material**

64318 - A 210 X 45 denier fabric of silicone coated nylon 6,6 Style No. 64318, available from Precision Fabrics Group, Greensboro, NC.

**Adhesives**

GE PSA529 - SILGRIP® PSA529 silicone pressure-sensitive adhesive available from GE Adhesives, Waterford, NY, mixed with 3.3 parts per hundred OSi A-1100 aminosilane crosslinking agent, commercially available from OSi Specialties, Inc., Endicott, NY.

Primer 1.0 - A 50/50 weight percent blend of OSi A-1100 and Y-11597, both available from Osi Specialties, Inc., Endicott, NY.

**Failure Mode**

FT - Fabric Tore  
SF - Seam Failure  
NF - No Failure

**Examples A & B**

Samples of silicone coated and uncoated nylon 6,6 fabrics were tested for adhesive-bond strength using the lap-shear and peel test methods described above. The GE PSA529/ OSi A-1100 adhesive mixture (i.e., the catalyzed GE PSA529) was applied to both sample strips of each sample. The samples bonded with the catalyzed GE PSA529 adhesive were allowed to cure for 7 days at room temperature, prior to testing. Coated fabrics were tested by bonding a coated side to an uncoated side, unless otherwise noted. The reported adhesion values are the average of three measurements. The results are shown in Table 1 below.

**TABLE 1**

Ex.	Fabric Type	Adhesive Type	Primer	Adhesion(N)		Failure Mode
				Peel	Shear	
A	PFG 64318	GE PSA529	None	23.1	411.5	FT
B	PFG 64318	GE PSA529	1.0	6.7	296.3	SF

**Airbag Examples C-F**

Octagon shaped airbags were fabricated by cutting two panels of PFG Type 64318 silicone coated nylon fabric. The first piece of fabric had a diameter of

approximately 365 mm and each side had a length of about 140 mm. The second piece of fabric had a diameter of approximately 391 mm with a side length of about 152 mm. A 44.5 mm diameter inflation hole was cut in the center of the second piece of fabric with six additional 6.5 mm diameter mounting holes located  
5 symmetrically around the inflation hole. The center of each mounting hole was about 65 mm from the edge of the inflation hole.

Two airbags were made by laying the first, smaller diameter piece of fabric on top of the larger diameter piece of fabric and aligning the centers of each piece. The top piece of fabric was rotated such that the weave of the top piece was about  
10 45° offset from the weave of the bottom piece. The fabric pieces were oriented such that the silicone coated side faced the inside of the restraint. Seams having a lap-shear geometry were formed by first cutting the larger diameter piece of fabric in each corner up to the overlaid smaller diameter fabric and forming tabs about 12.7 mm wide. The tabs were then folded onto the smaller diameter fabric and  
15 attached by sewing. Two rows of stitching were used to join the first and second pieces of fabric together. In one of the restraints, two 12.7 mm diameter vent holes were cut into the side of the restraint having the inflation hole. The vent hole were about 75 mm from the center of the vent hole and 180 degrees apart.

Two more airbags were assembled in similar fashion as above, except the  
20 seams were adhesively bonded in the following manner. A small amount of the catalyzed GE PSA529 adhesive (as described in Examples A-B above) was applied around the perimeter of each piece of fabric. The adhesive was allowed to dry for a few minutes and the 12.7 mm tabs were folded onto the first smaller diameter piece, and rolled with a 15 pound roller, forming seams having a lap-shear geometry. Two  
25 12.7 mm diameter vent holes were cut into one of the adhesively-bonded restraints as described above. The adhesively-bonded fabrics were allowed to cure for one week at room temperature.

Each of the assembled restraints were then attached to a 37.9 L air tank pressurized to 620-655 kPa via an 85 mm diameter flange. A solenoid-actuated ball  
30 valve was actuated quickly (< 50ms) to simulate deployment conditions of the restraint. Inflation pressures were collected using a transducer and the maximum



pressure obtained and the failure mode of each restraint was noted. Burst pressures and failure modes for each of the cushions tested are shown in Table 2 below.

**TABLE 2**

Ex.	Fabric Type	Chamber Style	Seam Attachment Means	Maximum Pressure (kPa)	Failure Mode
C	PFG 64318	Octagon (vented)	Sewn	108.8	FT
D	PFG 64318	Octagon	Sewn	96.5	FT
E	PFG 64318	Octagon (vented)	GE PSA529	36.8	SF
F	PFG 64318	Octagon	GE PSA529	96.5	FT

Subsequent to the airbag tests of TABLE 2, inflatable restraints have been fabricated using the catalyzed GE PSA529 adhesive, successfully deployed under real life conditions and successfully tested to meet industry standards. The below tabulated test results indicate that the other adhesives disclosed herein should also be suitable for bonding inflatable restraints.

Each of the shear strength values in TABLE 3, below, is an average of 3 to 5 samples tensile tested in shear. Tensile testing was all done on an Instron machine, with a 1000 lb (4448 N) load cell, at a crosshead speed of 12"/min. (30.48 cm/min.), a 3" (7.62cm) initial jaw gap (i.e., gage length), and 1.5 in. by 1 in. (3.8 cm by 2.54 cm) serrated metal clamps on 1" (2.54cm) wide adhesively bonded sample strips. The test samples used to generate the shear strength test results in TABLE 3 were made using 420 denier nylon fabric manufactured by Milliken & Co. of Lagrange, Georgia, except for the samples of Example 28, which were made with an approximately 520 denier blue colored nylon fabric obtained from TRW Automotive, Mesa, Arizona. Unless otherwise indicated, the samples for the Examples in TABLE 3 were prepared by applying the liquid adhesives with a foam applicator in an amount to visually and evenly cover the bond area. The two pieces that formed the bonded seam were put together right after they were coated. (no drying or curing time was used for these samples). Unless otherwise indicated, after the coated surfaces were overlapped, pressure was applied from a hand held roller

to form an overlapping seam; and each test sample was then allowed to stand for about 7 days before being tensile (shear) tested. As indicated in TABLE 3, these test samples were made from uncoated nylon fabric and nylon fabric having one side coated with silicone. In TABLE 3, the designations Si-Si, Ny-Si and Ny-Ny  
5 correspond, respectively, to samples of the silicone coated fabric strips where the overlapping surfaces being bonded are both coated (i.e., silicone to silicone), have one coated and one uncoated (silicone to nylon), and are both uncoated (nylon to nylon).

**TABLE 3**

Example	Uncoated Nylon Shear Strength (Psi/kPa)	Coated Nylon Shear Strength (Psi/kPa)		
		Si-Si	Ny-Si	Ny-Ny
1	76.5/527.5	183.7*/1266.6	99.8/688.1	107.6/741.9
2	106.3/732.9	207.3*/1429.3	107.7/742.6	77.0/530.9
3	100.6/693.6	212.6/1465.8	114.8/791.5	95.7/659.8
4	77.1/531.6	162.4/1119.7	94.0/648.1	90.1/621.2
5	98.6/679.8	138.2/952.9	101.7/701.2	97.6/672.9
6	78.1/538.5	128.1/883.2	112.3/774.3	103.3/712.2
7	82.5/568.8	147.1/1014.2	63.4/437.1	105.2/725.3
8	102.5/706.7	152.6/1052.1	123.6/852.2	117.9/812.9
9	80.8/557.1	90.1/621.2	66.3/457.1	108.4/747.4
10	104.1/717.7	214.6*/1479.6	117.0/806.7	127.1/876.3
11	71.0/489.5	174.4*/1202.5	112.1/772.9	93.5/644.7
12	102.3/705.3	186.6/1286.6	100.3/691.5	121.4/837.0
13	120.2/828.8	195.9*/1350.7	123.4/850.8	138.5/954.9
14	154.7/1066.6	193.0*/1330.7	166.2/1145.9	166.8/1150.1
15	132.7/914.9	204.9*/1412.7	129.7/894.3	131.5/906.7
16	89.2/615.0	186.2*/1283.8	115.3/795.0	49.9/344.1
17	84.1/579.9	190.2/1311.4	149.6/1031.5	112.9/778.4
18	67.7/466.8	195.9*/1350.7	106.6/735.0	134.7/928.7
19	72.2/497.8	149.0/1027.3	113.8/784.6	100.9/695.7
20	102.5/706.7	172.5/1189.4	109.5/755.0	97.3/670.9
21	103.4/712.9	153.1/1055.6	116.7/804.6	110.9/764.6
22	187.4/1292.1	193.4*/1333.5	201.4/1388.6	206.2/1421.7
23	ND	199.1*/1372.8	188.0*/1296.2	186.4/1285.2
24	171.8*/1184.5	209.3*/1443.1	201.8*/1391.4	179.7/1239.0
25	67.1/462.6	178.0*/1227.3	106.8/736.4	67.9/468.2
26	154.6/1065.9	227.2*/1566.5	142.3/981.1	161.7/1114.9
27	233.0*/1606.5	207.5*/1430.7	238.5*/1644.4	295.1*/2034.7
28	ND	259.0/1785.8	165.0/1137.6	ND
29	236.2*/1628.6	171.2/1180.4	149.2/1028.7	201.1/1386.5
30	206.8/1425.8	201.9/1392.1	194.1/1338.3	167.8/1156.9
31	65.2/449.5	205.6*/1417.6	159.4/1099.0	120.5/830.8
32	78.5/541.2	230.1*/1586.5	191.9/1323.1	149.1/1028.0
33	0	117.4/809.4	90.2/621.9	53.6/369.6
34	24.3/167.5	146.1/1007.3	95.7/659.8	118.8/819.1
35	11.7/80.7	119.1/821.2	111.2/766.7	104.2/718.4
Uncoated Nylon	257.0*/1772.0			
Si-Coated Nylon	256.7*/1769.9			

\* - indicates that at least one of the samples being averaged failed by the fabric tearing rather than the seam giving, as is usually the case.

**Examples 1-9**

The adhesives of Examples 1-9 are condensation cure-type pressure sensitive adhesives (PSA), where the components of each adhesive were blended at room temperature and mixed in the laboratory. Each of these exemplary adhesives contains a silicone-based polymer gum having condensation curable functional groups, an MQ resin containing condensation curable functional groups, toluene, and the multi-functional crosslinker aminosilane manufactured by OSI Specialties of Danbury, CT, under the product designation Silquest A-1100. For each of these Examples 1-9, a batch of the silicone gum, MQ resin and toluene are first blended together. Next, 6 parts of the A-1100 aminosilane, per 100 parts of solid polymer, is mixed with whatever amount of the resulting polymer gum blend is needed to make the desired number of samples. The resulting adhesive solution is applied to sample strips of the Milliken 420 denier nylon fabric, before any significant degree of curing of the adhesive occurs, to make the overlapping seam test samples.

Examples 1-3 were made using the low molecular weight (peak average molecular weight of 159,000 as determined by gel permeation chromatography) silicone polymer gum manufactured by Petrarch Systems, Inc., of Levittown, PA, under the product designation PS 199.5. Petrarch Systems, Inc., became Huls America, Inc., of Piscataway, NJ, which became Gelest, Inc., of Tullytown, PA. For the Examples 4-6, the silicone polymer gum was a medium molecular weight gum (peak average molecular weight of 428,000 as determined by gel permeation chromatography) manufactured by GE Silicones under the product designation GE 1048-374, lot GE001. For Examples 7-9, the silicone polymer gum was a high molecular weight gum (peak average molecular weight of 604,000 as determined by gel permeation chromatography) manufactured by GE Silicones under the product designation GE 1048-373, lot KC315. The MQ resin used for all of Examples 1-9 was SR545 resin solution (60 wt% solids in toluene) manufactured by GE Silicones of Waterford, New York. The amounts of polymer gum, MQ resin, and toluene used to form the adhesive solution for each of Examples 1-9 are listed in grams in TABLE 4 below.

The Examples 1-9 illustrate the effect of silicone polymer molecular weight, MQ resin concentration and cross-link density on shear strength.

**TABLE 4**

<b>Example</b>	<b>Silicone Gum (g)</b>	<b>MQ Resin Solution (g)</b>	<b>Toluene (g)</b>
1	25	48.3	27.2
2	25	65.9	29.7
3	25	92.3	33.4
4	25	48.3	27.2
5	25	65.9	29.7
6	25	92.3	33.4
7	25	48.3	27.2
8	25	65.9	29.7
9	25	92.3	33.4

**5    Examples 10-15**

Commercially available solvent based pressure sensitive adhesive were each mixed with 6 parts of the A-1100 aminosilane cross-linking agent, per 100 parts of adhesive solids. After the liquid PSA and aminosilane were mixed, the resulting condensation cure silicone adhesives were each used to make tensile (shear) samples as described above for Examples 1-9. For Examples 10, 11, 12, and 13, the silicone PSAs used were manufactured by Dow Corning under the product designations Q2-7406, 280A, 282 and Q2-7735, respectively. For Examples 14 and 15, the silicone PSAs used were manufactured by General Electric under the product designations 6573A and 529, respectively. These silicone PSAs were all received in solution.

**Examples 16-21**

In each of the Examples 16-21, a condensation cure-type silicone adhesive was prepared by blending a pressure sensitive silicone adhesive solution with a solution of an MQ resin in the proportions by weight (grams) indicated in TABLE 5, below. A desired amount of the resulting polymer blend was mixed with

6 parts of the A-1100 aminosilane cross-linking agent, per 100 parts of adhesive solids. This mixture was then used to make tensile test samples as described above for Examples 1-9. The silicone PSA solution used for Examples 16 and 17 was the Dow Corning PSA (received in solution) Q2-7406. The Dow Corning silicone PSA solution 280A was used for Examples 18 and 19, and the Dow Corning silicone PSA solution 282 was used for Examples 20 and 21. The MQ resin solution used for Examples 16-21 was made by adding 10.9 parts toluene to 120 parts GE SR545. The GE SR545 resin was added to increase the total MQ resin content of the resulting adhesive in an effort to improve the cohesive (shear) strength of the adhesive bond.

**TABLE 5**

<b>Example</b>	<b>PSA Solution (g)</b>	<b>MQ Resin Solution (g)</b>
16	50	14.3
17	50	30.4
18	50	14.3
19	50	30.4
20	50	10.2
21	50	25.5

**Examples 22-28**

Each of the samples in Examples 22, 23 and 28 were bonded with a room temperature vulcanizing (RTV) silicone adhesive. The General Electric neutral cure RTV167 and the Dow Corning neutral cure RTV3145 MIL-A-46146 were used to bond the tensile test samples for Examples 22 and 23, respectively. The tensile test samples of Examples 22 and 23 were made as described above for Examples 1-9 except after the adhesive was coated onto each fabric strip and the strips bonded together, the resulting samples were placed for 3 of the 7 days at 50°C in a forced air oven. A consumer silicone RTV caulk/sealant marketed under the name Cling n' Seal was used to bond the test samples of Example 28. The Cling'n Seal brand RTV silicone adhesive sealant came from the ITW Fluid Products Group,

Stock # 50050. These samples were not heated but simply stored at room temperature for 7 days before being tested.

Each of the Examples 24-27 used a thermal addition-cure (hydrosilation) silicone adhesive. The General Electric one-part silicone adhesives RTV6424, RTV6445 and TSE 322 were used for Examples 24, 25 and 26, respectively, and the Dow Corning two-part silicone adhesive Sylgard 577 was used for Example 27. One percent by weight of the adhesion promoter glycidoxypyrtrimethoxy silane (GPTS) was mixed with the General Electric TSE 322 adhesive before being used to bond the test samples of Example 26. The addition of 1 percent by weight of this adhesion promoter to the adhesives of Examples 24, 25, and 27 did not appear to result in an improvement in sample shear strength. Therefore, test data from such samples was not included herein. The test samples for Examples 24-26 (GE RTV6424, RTV6445, and TSE 322) were cured for 30 minutes at 150°C, and then stored at room temperature for seven days before being tested. The samples for Example 27 (DC Sylgard 577) were cured for 60 minutes at 150°C, and then stored at room temperature for seven days before being tested.

#### **Examples 29 and 30**

Both of the adhesives used to make the test samples for the Examples 29 and 30 are the silicone adhesive compositions disclosed in Examples 5 and 11, respectively, of the above incorporated co-pending U.S. patent application (U.S. Express Mail, Number TB895281035US), having the attorney Docket No. 53593USA6A.

For the samples of Example 29, polydimethylsiloxane polyurea segmented copolymer adhesive solutions were made by combining 17 parts by weight of the below described polydimethylsiloxane polyurea segmented copolymers, 25.5 part by weight of the MQ resin SR1000, available from General Electric Silicones of Waterford, NY, and 22.9 part by weight of a 50/50 toluene/2-propanol solvent mixture. These components were mixed until homogeneous. The adhesives were knife coated on 2 mil (.0508mm) PET release liner (Take-Off™ available from Rexam Release, Iowa City, Iowa), dried 15 minutes at room temp followed by 15 minutes at 70°C to obtain dry films of approximately 5 mil (0.127mm) thickness.

Overlap shear samples were then prepared by hot pressing the adhesive film between test strips of the sample fabric. The polydimethylsiloxane polyurea segmented copolymer for the Example 29 adhesive was made in the following manner. Silicone diamine,  $M_n = 5,320$ , was fed at a rate of 289 g/min into zone 8 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson NJ) and used as received, was injected at a rate of 13.3 g/min into zone 9. The screws were fully intermeshing, rotating at a rate of 200 revolutions per minute. The temperature profile of the extruder was: zones 1 through 7 (not used), zone 8 120°C, zones 9, 10, endcap, and melt pump 180°C. The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 23 of the above incorporated PCT Application No. PCT/US96/05869 (WO96/34029).

For the samples of Example 30, polydimethylsiloxane polyurea segmented copolymer adhesive solutions were made in the same manner as described for Example 29 except that 20 parts by weight of the below described polydimethylsiloxane polyurea segmented copolymer was combined with 46.7 parts by weight of the MQ resin SR1000 and 35.9 parts by weight of the 50/50 toluene/2-propanol solvent mixture. The polydimethylsiloxane polyurea segmented copolymer used in the Example 30 adhesive was made in the following manner. To a round bottom flask fitted with mechanical stirrer and static nitrogen atmosphere was added 100 pt of an aminopropyl terminated polydimethylsiloxane polymer (polydimethylsiloxane diamine) having molecular weight of 10,610. With mechanical agitation the contents of the flask were heated under aspirator vacuum to 110°C, allowed to degas 15 minutes, and cooled under static nitrogen atmosphere to 80°C before 287 pt of 50/50 toluene/2-propanol were added. With the flask maintained at 50°C a solution containing 2.3 pt tetramethylene-m-xylylene diisocyanate and 20 pt of 50/50 toluene/2-propanol was added and stirring continued for 16 hours to complete the reaction. The resulting clear viscous



solution was poured into a pan lined with release liner and allowed to dry under ambient conditions to provide a sheet of material.

It is believed that such adhesives containing amounts of copolymer and MQ resin in between the copolymer and MQ resin ratios used in Examples 29 and 30 would work well also.

### **Examples 31 and 32**

In Example 31, a moisture cure silicone adhesive was prepared as follows. To a glass jar purged with argon was added 50 parts polydimethylsiloxane diamine, molecular weight 10,412, that had been degassed at 100°C for 5 minutes under high vacuum, and 2.38 parts 3-isocyanatopropyltriethoxysilane (available from Silar Laboratories, Scotia, NY). The jar was capped and mixed slowly for 16 hours before 116.7 parts SR1000 MQ resin and 77.8 parts toluene were added and mixed to provide a homogenous adhesive solution. Aminopropyltriethoxysilane was added to this solution to provide 6 parts silane per 100 parts adhesive solids.

In Example 32, a moisture curable tackified polydimethylsiloxane oligourea segmented copolymer adhesive was prepared as follows. To a flask fit with mechanical stirrer, pressure-equalizing addition funnel, and positive argon atmosphere was added 50 parts of the degassed polydimethylsiloxane diamine of Example 31 and 50 parts toluene. In an argon purged vial a solution of 1.19 parts 3-isocyanatopropyltriethoxysilane, 0.63 parts methylenedicyclohexylene-4,4'-diisocyanate, and 25 parts toluene was prepared, charged to the addition funnel, and added slowly to the stirred flask. At the conclusion of the isocyanate addition the vial and addition-funnel were washed with a total of 25 parts toluene to introduce the last traces of the isocyanate charge to the flask. The flask contents stirred overnight to complete the preparation of the polydimethylsiloxane oligourea segmented copolymer solution. In a glass jar 145.8 parts copolymer solution and 114.6 parts SR1000 MQ resin were mixed to provide a homogeneous polydimethylsiloxane oligourea segmented copolymer adhesive solution. Aminopropyltriethoxysilane was added to the adhesive solution to provide 6 parts silane per 100 parts adhesive solids.

**Examples 33-35**

In Example 33, a free-radically curable tackified polydimethylsiloxane oligourea segmented copolymer adhesive was prepared using the procedure of Example 32 with the following exceptions. The solution of isocyanates added to the silicone diamine solution consisted of 0.74 parts isocyanatoethyl methacrylate (available as MOI from Showa Rhodia Chemicals, Tokyo, Japan), 0.63 parts methylenedicyclohexylene-4,4'-diisocyanate, and 25 parts toluene. The adhesive was prepared by mixing 145.6 parts polydimethylsiloxane oligourea segmented copolymer solution, 114.5 parts SR1000 MQ resin, and 6.54 parts of a 50% solution of 2,4-dichlorobenzoyl peroxide in silicone fluid (Perkadox PD-50S-ps-a available from Akzo Nobel Chemicals Inc. Chicago, IL).

In Example 34, a free-radically curable tackified polydimethylsiloxane oligourea segmented copolymer adhesive was prepared using the procedure and amounts of Example 33, with the exception that 4-methyl-2-pentanone was substituted for toluene.

In Example 35, a free radically curable silicone adhesive was prepared as follows. To a two-necked flask fit with mechanical stirrer and air drying tube was added 168.9 parts polydimethylsiloxane diamine, molecular weight 11,628. The silicone diamine was degassed at 100°C for 5 minutes under high vacuum and cooled to ambient temperature before 4.5 parts isocyanatoethyl methacrylate (available as MOI from Showa Rhodia Chemicals, Tokyo, Japan) was added to the stirred silicone diamine solution. Slow stirring continued overnight to provide a methacrylate terminated polydimethylsiloxane polymer. To a glass jar was charged 50 parts of the methacrylate terminated polydimethylsiloxane polymer, 116.7 parts SR1000 MQ resin, 6.66 parts of a 50% solution of 2,4-dichlorobenzoyl peroxide in silicone fluid (Perkadox PD-50S-ps-a available from Akzo Nobel Chemicals Inc. Chicago, IL), and 77.8 parts toluene.

The samples for Examples 33-35 were prepared by putting the bonded samples into a 340°F (171°C) heated press for 30 minutes, but the plates were shimmed so as not to squeeze adhesive beyond the desired bonding area.

**Examples 36 and 37**

The test samples for Examples 36 and 37 were strips of the uncoated and silicone coated 420 Denier Nylon fabric, respectively, manufactured by Milliken & Co.. These Examples provide the strength of the fabric as a reference.

The invention may further be illustrated by the following Example of an adhesive tape.

**Tape Example**

Uncoated white 420 denier, 47X47 weave, nylon fabric from Milliken & Co., of Spartanburg, South Carolina, was used as the backing for the adhesive tape. A silicone-coated fabric would also be suitable. A two-inch wide tape was prepared. A two-inch wide tape would give a one-inch wide seal on both sides of a butt joint seam application. The adhesive solution of Example 42 below was coated onto an HP Smith DR314 fluorosilicone coated 2 mil (.508 mm) polyethylene terephthalate release liner (6" wide) using a knife coater and dried at room temperature for 15 minutes, followed by exposure in a 66°C forced air oven to yield a non-tacky adhesive film about 6 mils thick.

It was determined that this adhesive could be applied to the fabric backing, then the liner could be removed by hand without the need for heat pressing. The fabric backed adhesive could then be bonded to another piece of fabric using a heat press at 160°C for 60 seconds, where the press was shimmed to avoid oozing of the adhesive past the desired bond line.

An 18" (45.7cm) long piece of backed adhesive tape was prepared using the uncoated Milliken fabric. A 20" (50.8cm) long and 2" (5.08cm) wide piece of the hand spread adhesive, dried on the liner, was cut out and applied to a two-inch wide strip of the 420 denier nylon. With the liner still on the adhesive, the fabric/adhesive/liner combination was heat pressed as described above. The nylon and the adhesive were set between two silicone-coated fiberglass sheets and then between two 0.013" (.33mm) thick aluminum sheets for the pressing. The press was shimmed to avoid oozing of the adhesive past the desired bond line.

After pressing, the 18" (45.7cm) long strip of the resulting adhesive tape had a good appearance, minimal curl, and the liner came off easily. The adhesive bonded well to the fabric backing, and it was non-tacky to the touch. The resulting backed adhesive tape appeared to be able to be rolled up onto itself without blocking.

As an alternative to the above tape forming process, such a solvent cast adhesive layer, or an extruded adhesive layer, can be laminated onto the fabric backing using a laminator with heated pressure rollers. For example, the adhesive layer, its release liner and the fabric backing were sandwiched together between two pieces of silicone coated fiberglass fabric so that the adhesive layer is sandwiched between the release liner and the fabric backing. The silicone coatings contact the release liner and the fabric backing. The resulting layered construction was run through a pair of pressure rollers, having a length of about 25.5 inches (64.8cm) and an overall diameter of about 1.5 inches (3.81cm). The diameter of each roller includes about a 0.5 inch (1.27cm) thick layer of rubber having a Shore A durometer of 55-60. The layered construction was processed through the pressure rollers at a rate of about 10 feet/min. (3.05m/min.). The rollers were heated using convection heaters set at a temperature in the range of about 149°C to about 190°C. The rollers were gapped so as to apply enough pressure, with the applied heat, to adequately activate the adhesive and laminate or bond the adhesive to the fabric backing.

Examples 29, 30 and 38-57 of silicone adhesives are of the type that contain a silicone-urea segmented copolymer and an MQ silicate resin. The following polydiorganosiloxane polyurea segmented copolymers were prepared by either a solvent based process or by a solventless (e.g., extrusion) process as described below. All polyisocyanates were used as received and the polyisocyanate:polyamine ratios were calculated using the polyisocyanate molecular weight reported by the polyisocyanate supplier and the polydiorganosiloxane diamine molecular weight as determined by acid titration.

**Polydimethylsiloxane Polyurea Segmented Copolymer A**

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson, New Jersey) and used as received, was fed into zone 1 of a Leistritz 18mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder at a rate of 0.737 g/min. Silicone diamine, Mn = 2,630 (Huls America, Inc. PS 510, lot 135,116), was injected at a rate of 7.9 g/min into zone 2. The screws were fully intermeshing, rotating at a rate of 40 revolutions per minute. The temperature profile of the extruder was: zone 1: 60°C, zone 2: 120°C, zone 3: 130°C, zone 4: 140°C, zone 5: 150°C, zone 6: 155°C, and zones 7 and 8: 170°C. The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 22 in the above incorporated PCT Application No. PCT/US96/05869 (Publication No. WO96/34029).

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**Polydimethylsiloxane Polyurea Segmented Copolymer B**

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. Silicone diamine, Mn = 5,320, was fed at a rate of 289 g/min into zone 8 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson NJ) and used as received, was injected at a rate of 13.3 g/min into zone 9. The screws were fully intermeshing, rotating at a rate of 200 revolutions per minute. The temperature profile of the extruder was: zones 1 through 7 (not used), zone 8 120°C, zones 9, 10, endcap, and melt pump 180°C. The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 23 of the above incorporated PCT Application No. PCT/US96/05869 (WO96/34029).

25

**Polydimethylsiloxane Polyurea Segmented Copolymer C**

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. To a round bottom flask fitted with mechanical stirrer and static nitrogen atmosphere was added 100 pt of a polydimethylsiloxane diamine having  
5 molecular weight of 10,610. With mechanical agitation the contents of the flask were heated under aspirator vacuum to 110°C, allowed to degas 15 minutes, and cooled under static nitrogen atmosphere to 80°C before 287 pt of 50/50 toluene/2-propanol were added. With the flask maintained at 50°C a solution containing 2.3  
10 pt tetramethylene-m-xylylene diisocyanate and 20 pt of 50/50 toluene/2-propanol was added and stirring continued for 16 hours to complete the reaction. The resulting clear viscous solution was poured into a pan lined with release liner and allowed to dry under ambient conditions to provide a sheet of material.

**Polydimethylsiloxane Polyurea Segmented Copolymer D**

15 A polydimethylsiloxane polyurea segmented copolymer was made in the same manner as Polydimethylsiloxane Polyurea Segmented Copolymer C except that the following reactant charges were employed, 3.83 pt silicone diamine, Mn = 11,784, 6.17 pt silicone diamine, Mn = 17,000, and 0.168 pt tetramethylene-m-xylylene.  
20

**Overlap Shear Sample Preparation and Testing**

Sample preparation for overlap shear testing is dependent on the form of the adhesive used, i.e., solid film adhesive, liquid adhesive, or paste adhesive. The preparation of an exemplary solid film adhesive overlap shear test sample is  
25 described below. In all cases samples constructed had an overlap shear area of about 2.54 cm<sup>2</sup>.

In the case of a solid film adhesive, a 2.54 cm x 17.8 cm strip of film adhesive on release liner was placed adhesive side down on a 12.7 cm x 17.8 cm piece of test fabric, the long dimension of the test fabric being in the cross web  
30 direction unless otherwise noted, such that the long dimension of the adhesive film was located directly atop and adjacent to the edge of the long dimension of the

5 fabric. The release liner was removed and a second piece of the same fabric having identical dimensions was placed on top of the adhesive strip to create an overlap shear sample having an overlap area of 2.54 cm. The sample was placed between two 6 mil thick siliconized glass cloth sheets backed with 12 mil thick aluminum sheets. The overlap shear construction was placed in a shimmed platen press at 160°C for 60 seconds to provide an overlap shear sample having a final bond thickness of about 3-4 mils (.0762mm-.102mm). Finished samples stood for 3-4 days at ambient condition before being cut into seven 2.54 cm x 17.8 cm strips. Each sample was mounted in an H-frame style testing machine, manufactured by 10 Instron Corp, Canton, Massachusetts, at a gauge height of 7.6 cm and pulled at a crosshead speed of 30.5 cm/min. The average of five individual tests is reported as the overlap shear strength.

#### **Adhesive Examples 38-54**

15 Polydimethylsiloxane polyurea segmented copolymer adhesive solutions were made by combining polydimethylsiloxane polyurea segmented copolymers, MQ resin, and 50/50 toluene/2-propanol in the ratios shown in TABLE 6 and mixing until homogeneous. All amounts are in parts by weight, unless indicated otherwise. The adhesives were knife coated on 2 mil (.0508mm) PET release liner 20 (Take-Off™ available from Rexam Release, Iowa City, Iowa), dried 15 minutes at room temp followed by 15 minutes at 70°C to obtain dry films of approximately 5 mil (0.127mm) thickness. Overlap shear testing samples were prepared using a nylon fabric available from Precision Fabrics Group, Inc., Greensboro, North Carolina of about 300 denier weight coated with silicone on one side. Overlap shear 25 samples were prepared and tested as described previously with the exceptions that the long dimension of the nylon fabric sheet was in the machine direction and the bond was created between the silicone coated side of the fabric and the uncoated side of the fabric. Results are reported below in TABLE 6.

**TABLE 6**

<b>Example</b>	<b>Segmented Copolymer</b>	<b>Segmented Copolymer (Parts)</b>	<b>SR1000 MQ (Parts)</b>	<b>Solvent (Parts)</b>	<b>Overlap Shear Strength (psi/kPa)</b>
38	A	17	20.8	20.3	44.5/307
39	A	17	25.5	22.9	31.9/220
40	A	17	31.6	26.2	21.7/150
41	B	17	20.8	20.3	141/972
42	B	17	25.5	22.9	152/1048
43	B	17	31.6	26.2	128/883
44	B	10	30	21.5	28.2/194
45	B	10	40	26.9	*
46	C	20	20	21.5	92.4/637
47	C	20	30	26.9	121/834
48	C	20	46.7	35.9	161/1110
49	C	10	30	21.5	42.7/294
50	C	10	40	26.9	*
51	D	20	24.4	23.9	89/614
52	D	20	37.1	30.8	99.7/687
53	D	10	30	21.5	44.9/310
54	D	10	40	26.9	*

\* - adhesive too fragile to construct samples due to high silicate resin content.

#### 5 **Adhesive Example 55**

A polydimethylsiloxane polyurea segmented copolymer adhesive was made in the following manner. Silicone diamine,  $M_n = 5,304.5$ , was fed at a rate of 57.8 g/min into zone 1 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. MQ silicone tackifying resin (GE Silicones, SR1000, lot FJ500) used as received, was fed at a rate of 90.72 g/min into zone 2. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson, New Jersey) and used as received, was injected at a rate of 2.6317 g/min into zone 9. The screws were fully intermeshing, rotating at a rate of 350 revolutions per minute. The temperature profile of the extruder was:



zone 1: 60°C, zones 2 through 10, endcap and melt pump: 170°C. The material was extruded through a strand die.

#### **Adhesive Example 56**

5           A polydimethylsiloxane polyurea segmented copolymer adhesive was made in the following manner. Silicone diamine,  $M_n = 10768$ , was fed at a rate of 22.74 g/min into zone 1 of a Berstorff 40mm diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. TMXDI, obtained from Cytek Industries (West Paterson, NJ) and used as received, was injected at a rate of 0.5211 g/min into  
10   zone 2. MQ silicone tackifying resin (GE Silicones, SR1000, lot FJ500) used as received, was fed at a rate of 52.97 g/min into zone 4. The screws were fully intermeshing, rotating at a rate of 300 revolutions per minute. The temperature profile of the extruder was: zone 1: 60°C, zone 2: 120°C, zones 3 through 10, endcap and melt pump: 170°C. The material was extruded through a strand die.

15

#### **Adhesive Example 57**

          The adhesive solution of Example 48 was used to create a hot-melt adhesive tape according to the following procedure. The adhesive solution was continuously applied, using a knife coater, to the polyethyleneterephthalate-based release film  
20   employed in Example 38, and passed through a three zone forced air oven having two 3.9 m zones and a final zone of 7.8 m, the three zones being at temperatures of 38°C, 49°C, and 66°C respectively, at a line speed of 1 m/min and wound up to provide a roll of hot-melt adhesive tape having an adhesive thickness of 2.5 mil (.0635mm). The tape roll was run through the same process again to overcoat the  
25   first layer of adhesive with a second layer of adhesive and obtain an overall adhesive thickness of 5 mil (.127mm). This adhesive was used to create overlap shear samples from two different 420 denier nylon fabrics available from Milliken & Company, Spartanburg, SC. Fabrics 1 and 2 were the same base fabric but fabric 2 was silicone coated on one side, thus the fabric had a nylon face and a silicone face.  
30   Fabric 2 was bonded together in three different fabric face orientations, nylon side to nylon side (N-N), nylon side to silicone coated side (N-S), silicone coated side to

silicone coated side (S-S). Overlap shear samples were prepared using a one inch (2.54 cm) width strip of adhesive as described above, with the exception that in this case the silicone coated glass cloth was not backed with aluminum plates, and rather than pressing the samples in a heat press they were fed through a heat laminator set at 190°C at a speed of 3.9 m/min. Overlap shear strength (OLS) test results are presented in TABLE 7.

**TABLE 7**

<b>Fabric</b>	<b>Fabric Faces Bonded</b>	<b>OLS (psi/kPa)</b>
1	Uncoated	204.4/1409
2	S-S	201.3/1388
2	N-S	197.7/1363
2	N-N	245.9/1695

Each of the shear strength values in TABLE 8, below, is an average of 3 to 5 samples tensile tested in shear. The test samples used to generate the shear strength test results in TABLE 8 were made using uncoated 420 denier nylon fabric manufactured by Milliken & Co. of Lagrange, Georgia. Each test sample was typically about 7 in. (17.78 cm) long, 1 in. (2.54 cm) wide and had a 1 in. (2.54 cm) overlap shear seam (i.e., a joint area of 1 in.<sup>2</sup> (6.45 cm<sup>2</sup>)). Up to five sets of test samples, 3 to 5 test samples in each set, were made for each of the adhesives of Examples 58-86 in TABLE 8. The 1" (2.54cm) wide adhesively bonded sample strips were each tensile tested using an Instron machine, with a 1000 lb (4448 N) load cell, at a crosshead speed of 12"/min. (30.48 cm/min.), a 3" (7.62cm) clamp gap width (i.e., gage length), and 1.5 in. by 1 in. (3.8 cm by 2.54 cm) serrated metal clamps.

Each test sample was preconditioned in a Constant Temperature/Constant Humidity (CTCH) room, at 70°F (21°C) and 50% relative humidity, before being tensile shear tested. For each adhesive Example listed in TABLE 8, a set of test samples were preconditioned in the CTCH room for at least four days and then tensile shear tested at room temperature. For most of the adhesive Examples (see

TABLE 8), two additional sets of test samples were preconditioned for at least three days and then the samples of one set were tensile shear tested at 90°C and the samples of the other set were tested at -40°C. For most of the adhesive Examples, two more sets of test samples were also preconditioned for at least three days, with the samples of one set then being aged in an oven at 107°C for 400 hours and the samples of the other set being aged in a cooler at -40°C for 400 hours. These aged samples were then further conditioned in the CTCH room for 1 to 2 days and finally tensile shear tested at room temperature.

10

**TABLE 8**

Example	RT Shear (Psi/kPA)	90C Shear (Psi/kPA)	-40C Shear (Psi/kPA)	107C Aged Shear (Psi/kPA)	-40C Aged Shear (Psi/kPA)
Uncoated Nylon	248.1*/1710.6*	210.0*/1447.9*	277.1*/1910.5*	ND	ND
58	141.5/975.6	101.3/689.4	150.2/1035.6	212.6/1465.8	143.2/987.3
59	167.8/1156.9	83.9/578.5	198.7/1370.0	213.8/1474.1	161.6/1114.2
60	139.7/963.2	81.7/563.3	163.6/1128.0	214.4/1478.2	140.2/966.6
61	159.5/1099.7	83.1573.0	176.8/1219.0	194.3/1339.7	149.6/1031.5
62	228.8/1577.5	87.5/603.3	284.5*/1961.6*	227.8*/1570.6*	210.3/1450.0
63	188.9/1302.4	80.9/557.8	285.7*/1969.8*	200.4/1381.7	189.7/1307.9
64	154.3/1063.9	57.7/397.8	77.0/530.9	138.1/952.2	176.0/1213.5
65	117.5/810.1	53.3/367.5	111.5/768.8	169.9*/1171.4*	111.5/768.8
66	248.6*/1714.0*	26.1/180.0	311.6*/2148.4	214.9*/1481.7*	216.0*/1489.3*
67	250.4*/1726.4*	25.1/173.1	91.9/633.6	229.4*/1581.7*	217.6*/1500.3*
68	256.4*/1767.8*	44.6/307.5	108.1/745.3	100.7/694.3	220.9*/1523.1*
69	204.2*/1407.9*	56.8/391.6	89.3/615.7	219.1*/1510.6*	225.2*/1552.7*
70	251.8*/1736.1*	22.1/152.4	69.0/475.7	217.2*/1497.5*	209.9*/1447.2*
71	221.3/1525.8	26.9/185.5	67.4/464.7	211.6*/1458.9*	196.1*/1352.1*
72	198.9/1371.4	47.9/330.3	70.1/483.3	223.2*/1538.9*	169.5/1168.7
73	199.9/1378.3	110.2/759.8	151.4/1043.9	94.1/648.8	205.7/1418.3
74	231.7/1597.5	34.4/237.2	63.1/435.1	212.1*/1462.4*	234.5*/1616.8*
75	90.7/625.4	ND	ND	195.1*/1345.2*	172.9/1192.1
76	109.0/751.5	22.1/152.4	88.8/612.3	141.2/973.5	92.4/637.1
77	158.3/1091.4	ND	ND	205.8*/1418.9*	143.2/987.3
78	148.3/1022.5	10.6/73.1	47.9/330.3	48.6/335.1	114.3/788.1
79	70.1/483.3	ND	ND	185.3*/1277.6*	69.9/481.9
80	202.2/1394.1	33.8/233.0	163.3/1125.9	ND	ND
81	195.0/1344.5	155.1/1069.4	141.5/975.6	93.8/646.7	233.7*/1611.3*
82	238.8*/1646.5*	102.9/709.5	63.0/434.4	191.5*/1320.3*	234.4*/1616.1*
83	190.2*/1311.4*	143.4/988.7	82.6/569.5	215.5*/1485.8*	224.9*/1550.6
84	249.0*/1716.8*	ND	ND	139.4*/961.1*	197.6*/1632.4
85	220.7/1521.7	91.2/628.8	303.9*/2095.3	202.7*/1397.6*	204.1*/1407.2*
86	223.9*/1543.7*	108.4/747.4	278.6/1920.9	210.2*/1449.3*	209.2*/1442.4*

**Key:**

\* = One or all samples tested in the indicated set failed by the nylon fabric tearing.

**5 Examples 58-63 (Silicone Adhesives)**

For each of the test samples of Example 58, the silicone pressure sensitive adhesive GE PSA529 with 3.3 pph of the A-1100 Aminosilane crosslinker was applied to the opposing sides of the pieces of uncoated nylon fabric to be bonded, using foam-tipped applicators. The bond was rolled with a 1-lb (454 g) roller using light hand pressure. The samples sat for 5 days before being tested. At least four of those days were in the CTCH room indicated above.

For each of the Examples 59-61, a solution of a peroxide-cure silicone adhesive was prepared by mixing 240 parts by weight (hereinafter "parts") of the PSA 6573A (available from General Electric Silicones, Waterford, NY) with a solution containing 0.71 parts Perkadox PD-50S-ps-a (50% by weight active 2,4-dichlorobenzoyl peroxide (DCBPO) available from Akzo Nobel Chemicals Inc. Chicago, IL), 0.0284 parts of the fluorescent dye Uvitex OB (optical brightener available from Ciba Specialty Chemicals, Toms River, NJ), and 43.8 parts toluene.

For each of the Examples 62 and 63, a polydimethylsiloxane polyurea segmented copolymer adhesive was used. This copolymer adhesive was made in the following manner: 100 parts of a polydimethylsiloxane diamine having a molecular weight of 10,610 and 90 parts toluene were added to a round bottom flask fitted with a heating mantle, mechanical stirrer, reflux condenser, and static nitrogen atmosphere. The flask contents were heated to 110°C and refluxed for 1 hour, cooled under static nitrogen atmosphere to 80°C, and 91.8 parts tertiary-amyl alcohol was added to the flask. With the flask contents stirring at 50°C a solution containing 2.3 parts tetramethylene-m-xylylene diisocyanate (TMXDI) and 1.8 parts toluene was added and temperature maintained for 16 hours to complete the preparation of this polydimethylsiloxane polyurea segmented copolymer. An adhesive solution was prepared by mixing to homogeneity 100 parts of this polydimethylsiloxane polyurea segmented copolymer solution, 66.5 parts SR1000 dry MQ resin, and 0.02 parts Uvitex OB.

The adhesive solution for each of these adhesive tapes (Examples 59-63) was knife coated on a 2 mil (.0508mm) thick PET liner, double-coated with fluorosilicone, from Rexam Release of Bedford Park, IL. In Example 59, the adhesive solution was coated onto the liner using a knife gap set to give a 5 mil  
5 (.127 mm) dry adhesive coating thickness. The adhesive coating was dried and cured by being passed through a 39 foot (9.14 m) oven, with three temperature zones of 107°F/166°F/294°F (42°C/74°C/145°C), at a line speed of 10 feet/minute (3.05 m/min.). The first two zones have a length of 9.75 feet (2.97 m) and the third zone had a length of 19.5 feet (5.94 m). The resulting roll of adhesive tape was slit  
10 down to 1" (2.54 cm) width rolls. In Example 60, the knife gap was set to coat the liner with a 3 mil (.076 mm) dry adhesive coating thickness. This adhesive coating was dried and cured by being passed through the 39 foot (9.14 m) oven of Example 59, with the three zone temperatures being set at 131°F/160°F/295°F (55°C/71°C/147°C). The line speed was 12 feet/minute (3.66 m/min.). In Example  
15 61, the adhesive solution was handspread onto the liner using a knife coater with a gap set to obtain a 3.25 mils (.083 mm) dry adhesive thickness. The handspread coating was dried for 15 minutes at 70°F (21°C) and then cured for 15 minutes in an oven at 150°F (66°C).

In Example 62, two layers of the adhesive solution were knife coated, one  
20 after the other, on the PET liner using two passes with the knife gap set to give each layer a 2.5 mil (.06 mm) dry adhesive coating thickness, for a total coating thickness of 5.0 mil (.12 mm). The double layer adhesive coating was dried and cured by being passed through the 39 foot (9.14 m) oven of Example 59, with the three temperature zones being set at 119°F/145°F/218°F (48°C/63°C/104°C). The  
25 line speed was 5 feet/minute (1.5 m/min.). In Example 63, only one layer of the adhesive solution was knife coated on the liner using one pass with a knife gap set to give a 2.5 mil (.06 mm) dry adhesive coating thickness. This single layer adhesive coating was dried and cured by being passed through the 39 foot (9.14 m) oven of Example 59, with the three temperature zones being set at  
30 117°F/147°F/217°F (47°C/64°C/103°C). The line speed was 10 feet/minute (3.05 m/min.).

In the shear strength testing of Examples 59-63, each of the samples used 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) pieces of the adhesive cut from a slit tape roll (Examples 59, 60, 62, 63) or cut out of handspreads (Example 61). They were applied to one piece of the fabric, the liner was removed, then the other piece of fabric was placed over the adhesive to make a 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) overlap seam. The samples were then run through the laminator described in the above disclosed tape forming process, with each of the rolls being at 190 °C, and at a roll speed of 1.5 feet/minute (45.7 cm/min.).

10 **Examples 64-69 (Thermoplastic Films and Webs)**

The adhesive used for the samples of Example 64 is a non-woven polyester Thermo-Bond Web (TBW) manufactured by 3M Company of St. Paul, Minnesota, under the product # 695 and having a thickness of 10 mil (0.25 mm). The adhesive of Example 65 is an ethylene acrylic acid (EAA) Thermo-Bond Film (TBF) manufactured by 3M Company under product # 406 and having a thickness of 3 mil (0.08 mm). Example 66 is a polyolefin TBF #845, Examples 67 and 68 are each a polyester TBF # 615 and # 667, and Example 69 is a polyamide TBF # AHS 194 manufactured by 3M Company. Each of the adhesive tapes of Examples 66-69 has a thickness of 4 mil (0.10 mm).

20 For each of the Examples 64-69, the nylon fabric and adhesive tape were sized to provide samples having 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) shear seams. The samples were then run through the above described roll laminator, with each of the rollers being at 310°F (155°C), at a roll speed of 0.25 feet/minute (7.62 cm/min.). Then all the samples were placed between two 24" x 24" (61cm x 61cm) and 11 mil (.28 mm) thick aluminum plates clamped at the edges with medium binder clamps and placed in a 290°F (142°C) oven for 20 minutes.

25 In addition, satisfactory shear strength results have been obtained from test samples made with urethane coated nylon fabric bonded with the above type of thermoplastic adhesives, in particular those of Examples 64, 65, 67 and 68. Overlap shear strength results ranging from 63.2 psi to 203.8 psi were obtained at room temperature testing.

**Examples 70-72 (Epoxy/Acrylate Structural Hybrid)**

The adhesives of Examples 70-72 are acrylate/epoxy UV activated, room temperature curable structural hybrid tape, tackified or not tackified versions.

These adhesives are based on a BA/MA (Butyl acrylate/Methyl acrylate) copolymer made by bottle polymerizing (i.e., rotated 24 hrs in a water bath heated to 55°C.) 16.1wt% BA and 83.9 wt% of MA at 50% solids in 78wt% EA and 22 wt% IPA (Ethyl Acetate/isopropyl alcohol), with 2 wt% based on solids (i.e., the amount of BA/MA) of the thermal initiator VAZO- 64 (free radical source- 1,1-Azobis (cyclohexanecarbonitrile)) from DuPont, Wilmington, Delaware.

The particular adhesive of Example 70 is made by adding in an amber jar 12.5g of a 50/50 blend of EPON 828/XB4122 to 50g of the above 50% solids BA/MA copolymer (in EA/IPA). To this is added 0.76g of the UV initiator Triarylsulfonium salt (e.g., CD1010). EPON 828 is a diglycidyl ether of bisphenol A (DGEBA) epoxy resin from Shell Chemical Co. of Houston, Texas, and XB4122 is a Bisphenol A based epoxy resin from Ciba-Geigy, of Hawthorne, New York.

The adhesive of Example 71 is made by adding in an amber jar 3.3g of a hydrogenated synthetic hydrocarbon tackifier resin ECR-180 (from Exxon of Baton Rouge, LA) and 12.5g of a 50/50 blend of EPON 828/XB4122 to 43.5g. of the above 50% solids BA/MA copolymer (in EA/IPA). To this is added 0.76g of the UV initiator CD1010. The adhesive of Example 72 is made by adding in an amber jar 5.8g of ECR-180 and 12.5g of a 50/50 blend of EPON 828/XB4122 to 38.5g. of the above 50% solids BA/MA copolymer (in EA/IPA). To this is added 0.76g of the UV initiator CD1010.

All samples were coated out of solvent on Siliconized 2 mil (.051 mm) PET liner and dried for 10min. at 21°C, then 10min. at 40°C, and finally 10min. at 65°C.

The samples of Example 70 were coated at 0.65mm thickness in order to get 0.25mm (10mils) dry thickness. The rest of the samples were coated at 0.5mm in order to get 7mils (.178 mm) dry thickness. Each of the samples were prepared and cured as follows: Each adhesive tape was cut to size (to provide a 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) shear seam) and applied to a first substrate of the nylon fabric, rolled more than 2 times with a 5 lb. (2.27 Kg) rubber roller and then activated with two exposures to

UV light from a processor made by Fusion Corporation of Rockville, Maryland. The UV processor has a feed rate of around 45 ft/min (13.7 m/min.) for each pass and is fitted with a "D" - bulb, at a total intensity of 500mJ/sq.cm. per pass. A second substrate of the nylon fabric was applied immediately after activation. Once again, rolled over 2 times with the 5lb. (2.27 Kg) rubber roller and clamped together with 2 big binder clips and 2 strips of aluminum to transfer pressure to the sample uniformly and provide support during cure. Then the samples undergo thermal cure acceleration at 100°C for 25min.

10 **Example 73 (PolyUrea)**

The adhesive of Example 73 is a two part polyurea adhesive in the line of Scientific Anglers Ultraflex Adhesives available from 3M Company, Part # 34-8501-6258-6. The samples for Example 73 were prepared by placing 1.58 grams of Part A and 1.68 grams of Part B into separate parts of a small plastic cup, followed by 4 grams of toluene. All three components were then mixed together rapidly using a tongue depressor to achieve a homogeneous mixture. The resultant liquid was then applied with foam-tipped applicators to a 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) seam area of the uncoated 420 denier nylon and a bond was made to give a 1" (2.54 cm) overlap seam, then the seam was roll flattened with a 1 lb. (454g) rubber roller using hand pressure. The test samples were left to sit for 2 days before being moved. The bonded pieces were then conditioned in a Constant Temperature/Constant Humidity (CTCH) Room (21°C/50% RH) for 4 days before being tested.

**Example 74 (Epoxy/Polyester Structural Hybrid)**

25 The following adhesive formulation at 10 mils (.25 mm) thickness was used to make the test samples for Example 74:

	Dynapol S 1313	20.0 wt%
	Dynapol S 1402	57.8 wt%
30	EPON 1001	20.0 wt%
	Voranol 230-238	1.0 wt%
	CD1010	1.2 wt%



All percentages are based on weight. Each Dynapol component is a thermoplastic polyester from Crenova Inc. (previously Huls) of Middletown, New Jersey. The EPON 1001 is an epoxy resin from Shell Chemical Co. Voranol 230-238 is a polyester polyol from Dow Chemical Co. of Midland, Michigan. The CD1010 is a photoinitiator from Sartomer of West Chester, Pennsylvania.

The procedure for making the above adhesive film is as follows: The first four raw materials listed above were weighed and placed in a metal vessel. The vessel with the raw materials was placed in an oven at 350°F (177°C) for about 15 min. until melted. The materials were then mixed and placed in an oven at 250°F (121°C) for about 15 mins. and stirred occasionally. After the mixture was homogeneous, the CD1010 was added and stirred with further heating for about 5 min. The sample was removed and coated between two silicone treated Kraft type paper release liners using a heated knife coater. The temperature of the bar and bed of the knife coater was set at 260°F (127°C). The gap between the bar and bed of the knife coater was set to obtain a 10 mil (.25 mm) dry adhesive thickness. The resulting adhesive films were placed in the dark and allowed to cool.

The following procedure was used to prepare the samples for Example 74:

One side of the release liner was removed from the adhesive film and laminated to the nylon fabric using a press at 40lbs. (18.2 Kg) for 5 sec. at 300°F (149°C). After the sample cooled, the second release liner was removed, and the sample was exposed to UV light from a processor made by Fusion Corporation of Rockville, Maryland, and fitted with an H bulb, at a total intensity of 502.2 MiliJoules/cm<sup>2</sup>.

The second piece of the nylon fabric was placed on top of the adhesive, placed in the press described below for Examples 83 and 84 and pressed for 5 sec. at 300°F (149°C) until laminated together.

**Examples 75-77 (Flexible Epoxies)**

The adhesive films used in Examples 75-77 have the following compositions:

Example. 75 = Vamac G - 30g; EPON 1462 (Shell) - 20g; and  $\text{Ar}_3\text{S}^+\text{SbF}_6^-$  - .05g.

5 Example 76 = Vamac D - 35g; EPON 1462 (Shell) - 15g; and  $\text{Ar}_3\text{S}^+\text{SbF}_6^-$  - .05g.

Example 77 = Vamac D - 30g; EPON 1462 (Shell) - 20g; and  $\text{Ar}_3\text{S}^+\text{SbF}_6^-$  - .05g.

Vamac is an acrylic rubber from DuPont of Wilmington, Delaware.

The adhesive films for Examples 75-77 were all prepared by blending the corresponding components in a Brabender mixer at 100°C. The Vamac acrylic  
10 rubber component was first added in the mixer and allowed to melt. The EPON epoxy component was then added slowly over a 15-20 minute period. After all the epoxy was added and the blend appeared homogeneous, the  $\text{Ar}_3\text{S}^+\text{SbF}_6^-$  catalyst was added, and mixing was terminated one minute after catalyst addition. The resulting adhesive was protected from light. To obtain films, the adhesive was  
15 pressed to a thickness of 10 mils (.254 mm), using a Carver press, between Teflon sheets at 280°F (138°C).

The test samples for Examples 75-77 were prepared by applying the corresponding adhesive film to one piece of the uncoated nylon fabric using a rubber roller (no heat). The release liner was removed, and the samples were  
20 exposed to a medium pressure mercury lamp for 5 minutes in an M-218 processing unit made by Colight of Minneapolis, Minnesota, at a total intensity of 840 MiliJoules/cm<sup>2</sup> at 365 Nm and 1900 mJ/cm<sup>2</sup> at 400 Nm. The second piece of nylon fabric was placed onto the adhesive and some pressure was applied using the rubber roller. The samples were run two times through a roller heated to 300°F at around  
25 7 inches/min. (149°C at around 17.8 cm/min.), turning the sample over after the first pass. The samples were post-cured for 30 minutes at 125°C.

**Examples 78 and 80 (Tackified Block Copolymers)**

30 The adhesive film used in Example 78 has the following composition:

49.7 wt% polyether/polyamide block copolymer (PEBAX 3533 Available from ELF ATOChem Glen Rock, NJ)

49.7 wt% terpene phenolic tackifier (Nirez 2040 available from Arizona Chemical, Panama City Florida)

5        0.6 wt% 4,4'((alpha),(alpha)-dimethylbenzyl)diphenylamine antioxidant (Naugard 445 available from Uniroyal Chemical Co., Middlebury, CT)

The adhesive was compounded in a counterrotating twin screw extruder and cast as a film at 120°C onto a silicone-coated release liner. This composition is disclosed in US Patent No. 5,672,400, which is incorporated herein by reference in  
10 its entirety.

The adhesive film used in Example 80 has the following composition:

59.7 wt% polyether/polyamide block copolymer (PEBAX 3533, available from ELF ATOChem Glen Rock, NJ)

39.7 wt% rosin modified phenolic resin tackifier (Tamanol 135, available  
15 from Arakawa Chemical (USA) Chicago, Illinois).

0.6 wt% 4,4'((alpha),(alpha)-dimethylbenzyl)diphenylamine antioxidant (Naugard 445, available from Uniroyal Chemical Co., Middlebury, CT)

The adhesive was compounded in a counterrotating twin screw extruder and cast as a film at 160°C onto a silicone-coated release liner. This composition is also  
20 disclosed in the above incorporated US Patent No. 5,672,400.

The test samples for Example 78 were prepared by laminating the adhesive film to one piece of the uncoated nylon fabric, by placing on a hot plate at 100°C and using a roller to apply pressure. The release liner was removed, and the second piece of Nylon fabric was placed onto the adhesive and some pressure was applied  
25 using a rubber roller. The sample was run two times through a roller heated to 300°F at around 7 inches/min (149°C at around 17.8 cm/min.), turning the sample over after the first pass. The test samples for Example 80 were prepared like those of Example 78, except they were subsequently pressed in the Carver press for 30 sec at 350°F (175°C).

**Example 79 (Polyolefin Rubber Adhesive)**

The adhesive film used in Example 79 is a mixture of a maleated polybutadiene/ethylene propylene diene monomer (EPDM) rubber (Ricobond EP 3) from Ricon Resins Inc, Grand Junction, CO. The test samples for Example 79 were prepared using the same procedure as above for Example 78, except that a 20 minute post bake at 125°C followed the hot lamination.

**Examples 81-84 (Epoxy/Polyolefin Structural Hybrid)**

The adhesive used in Example 81 comprises a thermoplastic base: 59.9% by weight of Vestoplast 750; 28.0% by weight of DS7C50; and 12.1% by weight of Epolene G3003. The epoxy loading was 3.7% EPON 828 (2% S-cat). Vestoplast 750 is a polyalphaolefin from Hüls (Hüls America Inc., Piscataway NJ) with a propylene-ethylene-butylene backbone. DS7C50 is a propylene homopolymer with 20% by weight of fully saturated ethylene-propylene rubber. It is made by Union Carbide Chemicals and Plastics Inc. (Danbury, CT). S-cat is an abbreviation for triarylsulfonium hexafluoroantimonate ( $\text{Ar}_3\text{SSbF}_6$ ). This adhesive was extruded with the 400°F (204°C) extrusion profile described below.

The adhesive used in Example 82 comprises a thermoplastic base: 65% Vestoplast 750; 30% Bynel XB602; and 5% Dicy CG1400. The epoxy loading was 2% EPON 828 (2% S-cat). Dicy is short for dicyandiamide or cyanoguanidine. It is a curing agent for epoxy. CG1400 is sold by Air Products and Chemicals Inc. (Pacific Anchor Chemical, Allentown PA). Bynel XB602 is an experimental grade epoxidized polypropylene made by Dupont (Dupont DeNemours, Willmington DE). Extrusion temperatures were set at or below 300°F (149°C).

The adhesives used in Examples 83 and 84 each comprises a thermoplastic base: CA10G + 2.5% epolene G3003, 2% EPON 828 (with 2% S-cat). CA10G is a polypropylene with 55% ethylene-propylene rubber content. Epolene G3003 is a maleated polypropylene from Eastman Chemical (Kingsport, TN). Its molecular weight is 52,000 and its maleation content is around 1%. EPON 828 is an aromatic epoxy (diglycidyl ether of bisphenol A) and it is available from Shell Chemical

Company. S-cat is an abbreviation for triarylsulfonium hexafluoroantimonate ( $\text{Ar}_3\text{SSbF}_6$ ). This catalyst is added at 2% by weight of epoxy. The epoxy and the catalyst are premixed in a kettle and then pumped to the extruder using a gear pump. In particular, a Zenith (Zenith Pumps Division of Parker Hannifin Corporation, Sanford NC) HPB 4740 pump with a capacity of 0.168 cc/rev. The pumped mixture was extruded at 400°F (204°C) setpoint. Temperatures from feed zone to die were: 360°F, 395°F, 400°F, 400°F (182°C, 202°C, 204°C, 204°C).

All the samples for Examples 81-84, above, were made in a Haake (Haake, Paramus NJ) conical intermeshing counterrotating twin screw extruder with four heating zones. The temperature profile for each composition is noted above. The barrel diameters are (Rear/Front): 31.8/20mm. All samples were collected using a high torque-low speed C.W. Brabender Instruments Inc. (South Hackensack NJ) take off unit, model #SFR-100. Roll temperatures were set to 20 °C. A six inch (15.24 cm) film die was used with no neck tube. Films ranged from 0.5 to 20 mils (.012 to 0.51 mm) in thickness.

The overlap shear test specimens for Examples 81-84 were made using a 5x5 in. (12.7x12.7 cm) Carver Hydraulic Press, model C (Carver Press Inc. Wabash IN). No pressure was used, just contact with the platens. The above described nylon fabric was the substrate for all samples. The samples were sandwiched between 15 mil (.38 mm) Teflon sheets. All curing times were 2 minutes. The press temperature utilized was 300°F (149°C) for Examples 81 and 82, 350°F (177°C) for Example 83, and 400°F (204°C) for Example 84. The adhesive films were extruded on the same PET liner with silicon release on only one side (that the side that was extruded or pressed onto). The liner is a Dupont product A18010.

The type of adhesive used in Examples 81-84 is disclosed in US Patent 5,709,948, issued on 1/20/98, which is incorporated herein by reference in its entirety.

**Examples 85 and 86 (PolyUrethanes)**

The adhesive used for both Examples 85 and 86 is an RTP Two-part urethane, available from 3M Company, Part # 051131-08535, which comes in a packet.

5        The samples for Examples 85 and 86 were prepared by breaking the membrane between the two parts of the adhesive, and then vigorously and rapidly mixing the packet into a ball, by hand. The mixture was rolled and squeezed for 1.75 minutes. The packet was then laid on the table and pressed flat. One end of the packet was cut off and, for the Example 85 samples, the black paste inside the  
10       packet was applied neat to a 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) seam area of 420 denier uncoated Milliken nylon fabric test pieces using a tongue depressor. The seams were then rolled down flat with a 1 lb (454g) rubber roller using hand pressure.

For the Example 86 samples, 52.3 grams of the paste was put into a 100 ml plastic beaker along with 13.9 grams of toluene and mixed with a tongue depressor  
15       to give a solution. This solution was then applied with a foam tipped applicator to the 1 in<sup>2</sup> (6.45 cm<sup>2</sup>) seam area of 420 denier uncoated Milliken nylon fabric test pieces. The seams were then rolled down flat with the 1 lb (454g) rubber roller using hand pressure.

The use of an adhesive tape to bond a structural seam of an inflatable  
20       restraint eliminates the need to sew the seam together (a cumbersome, time consuming process that can also compromise the integrity of the inflatable restraint, as discussed above). In addition, employing a butt joint seam geometry eliminates the need to overlap portions of the fabric brought together to form the seam. Where overlap seams are used to form a structural seam, the use of an adhesive  
25       tape to bond the seam eliminates the need for a liquid adhesive. Eliminating the need for a liquid adhesive provides a more user friendly environment for fabricating inflatable restraints. The use of a tape to bond structural seams, or as described below, to reinforce inflator holes, vent holes, and the like, advantageously allows for the use of lighter weight fabrics; no sewing is required and the fabric will not be  
30       subject to combing upon deployment. The use of a tape to bond structural seams of

an inflatable restraint may offer additional applications and design options for inflatable restraint devices, and improve the ease of manufacture of such devices.

With the teachings of the present invention, various modifications and alterations to this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention. For example, the fabric  
5 coating and the adhesive can be one and the same. It should be understood that this invention is not intended to be limited by the embodiments and examples set forth herein and that such examples and embodiments are presented by way of example only with the scope of the invention intended to be limited only by the claims set  
10 forth herein as follows.

What is claimed is:

1. An inflatable restraint comprising:  
an inflatable chamber comprising at least one sheet of a material  
5 suitable for use in an inflatable restraint and one or more structural seams, each  
structural seam being formed by at least two edges of said at least one sheet, said  
inflatable chamber having a substantial portion of at least one structural seam  
bonded with an adhesive selected from the group consisting of polyether/polyamide  
block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives,  
10 acrylate/silicone adhesives, ethylene/acrylic acid adhesives, polyurethane adhesives,  
polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, polyolefin  
rubber adhesives, epoxy/polyolefin adhesives, polyamide adhesives, polyurea  
adhesives and combinations thereof, and said adhesive being formulated and  
prepared such that said at least one structural seam is capable of withstanding  
15 inflation forces resulting from deployment of said inflatable restraint, when said  
structural seam is bonded with said adhesive.
2. The inflatable restraint of claim 1, wherein said at least one structural  
seam has a lap shear geometry formed by said two edges overlapping each other so  
20 as to form overlapping portions of said at least one sheet, and said adhesive is  
disposed between said overlapping portions so as to bond said at least one  
structural seam.
3. The inflatable restraint of claim 1, wherein said adhesive comprises a  
25 polyether/polyamide block copolymer.
4. The inflatable restraint of claim 1, wherein said adhesive is an  
acrylate adhesive.
- 30 5. The inflatable restraint of claim 1, wherein said adhesive an  
acrylate/epoxy adhesive.



6. The inflatable restraint of claim 1, wherein said adhesive is an ethylene acrylic acid adhesive.

5 7. The inflatable restraint of claim 1, wherein said adhesive is a polyurethane adhesive.

8. The inflatable restraint of claim 1, wherein said adhesive is a polyester adhesive.

10 9. The inflatable restraint of claim 1, wherein said adhesive is a polyester/epoxy adhesive.

10. The inflatable restraint of claim 1, wherein said adhesive is a polyolefin adhesive.

11. The inflatable restraint of claim 1, wherein said adhesive is an epoxy/polyolefin adhesive.

12. The inflatable restraint of claim 1, wherein said adhesive is a polyolefin rubber adhesive.

13. The inflatable restraint of claim 1, wherein said adhesive includes a pigment, dye, or colorant agent in an amount sufficient to render the adhesive detectable.

14. An inflatable protective device comprising:  
a housing;  
an inflation device attached to the housing; and  
an inflatable restraint comprising an inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive so as to

have a lap-shear geometry, said adhesive being selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, ethylene/acrylic acid adhesives, polyurethane adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, polyolefin rubber adhesives, epoxy/polyolefin adhesives, polyamide adhesives, polyurea adhesives and combinations thereof, and said adhesive being formulated and prepared such that said at least one structural seam is capable of withstanding inflation forces resulting from deployment of said inflatable restraint, when said structural seam is bonded with said adhesive tape.

10

15. A method of making an adhesively-bonded inflatable restraint comprising the steps of:

providing an adhesive selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, ethylene/acrylic acid adhesives, polyurethane adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, polyolefin rubber adhesives, epoxy/polyolefin adhesives, polyamide adhesives, polyurea adhesives and combinations thereof, and at least one sheet of a material suitable for use in an inflatable restraint, the sheet having two edges;

15

overlapping the two edges of the sheet so as to form a seam having a lap shear geometry and to form at least part of an inflatable chamber;

20

disposing the adhesive between the overlapping edges of the sheet;

and

activating the adhesive so as to bond the overlapping edges together,

25

wherein the adhesive is formulated and prepared such that the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint, when the overlapping edges are bonded with the adhesive.

16. The method of claim 15, wherein the adhesive being provided is a curable adhesive, said method includes the step of curing the adhesive after said step of activating the adhesive, and the resulting seam is capable of withstanding

30

inflation forces resulting from deployment of the inflatable restraint, after the adhesive is substantially cured.

17. The method of claim 15, wherein the at least one sheet being  
5 provided is at least two sheets of a material suitable for use in an inflatable restraint, with each sheet providing one of the at least two edges.

18. The method of claim 15, wherein said step of disposing the adhesive  
between the overlapping edges of the sheet includes bonding the adhesive along at  
10 least one of the edges before said step of overlapping the two edges of the sheet.

19. An inflatable restraint comprising an inflatable chamber, said  
inflatable chamber comprising at least one sheet of a material suitable for use in an  
inflatable restraint and one or more structural seams, each structural seam being  
15 formed by at least two edges of said at least one sheet, said inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive tape selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate/epoxy adhesives, ethylene acrylic acid adhesives, polyester  
adhesives, polyester/epoxy adhesives, polyolefin adhesives, polyolefin rubber  
20 adhesives, epoxy/polyolefin adhesives, polyamide adhesives, and combinations thereof,

wherein said adhesive tape is formulated and prepared such that said at least  
one structural seam is capable of withstanding inflation forces resulting from  
deployment of said inflatable restraint, when said structural seam is bonded with  
25 said adhesive tape.

20. The inflatable restraint of claim 19, wherein said tape comprises a  
backing having two major surfaces and an adhesive on at least one major surface,  
said backing and said adhesive being selected such that said at least one structural  
30 seam is capable of withstanding inflation forces resulting from deployment of said inflatable restraint, when said structural seam is bonded with said tape.

21. The inflatable restraint of claim 20, wherein said at least one structural seam has a butt joint geometry formed by said two edges, and said tape overlaps said edges so as to bond said structural seam.

5

22. The inflatable restraint of claim 20, wherein said adhesive is on both major surfaces, said at least one structural seam has a lap shear geometry formed by said two edges overlapping each other so as to form overlapping portions of said at least one sheet, and said tape is disposed between said overlapping portions so as to bond said structural seam.

10

23. The inflatable restraint of claim 19, wherein said tape is an adhesive transfer tape comprising at least one adhesive layer without a backing, said adhesive layer being selected such that said at least one structural seam is capable of withstanding inflation forces resulting from deployment of said inflatable restraint, when said structural seam is bonded with said tape.

15

24. The inflatable restraint of claim 23, wherein said at least one structural seam has a lap shear geometry formed by said two edges overlapping each other so as to form overlapping portions of said at least one sheet, and said adhesive transfer tape is disposed between said overlapping portions so as to bond said structural seam.

20

25. The inflatable restraint of claim 19, wherein said inflatable chamber further comprises a retaining ring assembly, said retaining ring assembly comprises at least one retaining ring bonded about the periphery of an opening in said inflatable chamber by at least one adhesive layer.

25

26. The inflatable restraint of claim 25, wherein said retaining ring and said at least one adhesive layer form a backed adhesive tape.

30

27. The inflatable restraint of claim 19, wherein said inflatable chamber further comprises a retaining ring assembly, said retaining ring assembly comprises at least one retaining ring bonded about the periphery of an opening in said inflatable chamber on an inner surface of said inflatable chamber, at least one other  
5 retaining ring bonded about the periphery of said opening on an outer surface of said inflatable chamber, and each said retaining ring being bonded using at least one layer of an adhesive.

28. The inflatable restraint of claim 19, wherein said inflatable chamber  
10 has two opposing inner surfaces, said inflatable restraint includes a tether having opposite ends and a length, each end of said tether is bonded to one of said opposing inner surfaces of said inflatable chamber with an adhesive layer so that said adhesive layer is subjected to substantially tensile loading, not peel loading, during the inflation of said inflatable chamber as said inflatable restraint is deployed,  
15 said adhesive layer is selected so as to withstand the inflation forces resulting from deployment of said inflatable restraint and maintain the bond between said tether and said opposing inner surfaces, and the length of said tether limits the separation of said opposing inner surfaces during the inflation of said inflatable chamber.

20 29. A tape useful for bonding a structural seam of an inflatable restraint, said tape comprising at least one adhesive layer selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate/epoxy adhesives, ethylene acrylic acid adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, epoxy/polyolefin adhesives, polyolefin rubber adhesives,  
25 polyamide adhesives, and combinations thereof, said adhesive being formulated and prepared such that when used to bond a structural seam of an inflatable restraint, the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint.

30 30. The tape of claim 29, wherein said at least one adhesive layer is self-supportive without a support backing.

31. The tape of claim 29, wherein said tape further comprises a backing having two major surfaces and at least one adhesive layer is on at least one major surface, said backing and said at least one adhesive layer being selected such that  
5 when used to bond a structural seam of an inflatable restraint, the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint.

32. A method of making an inflatable restraint comprising the steps of:  
10 providing at least one sheet of a material suitable for making an inflatable restraint, with the at least one sheet having two edges, and an adhesive tape selected from the group consisting of polyether/polyamide block copolymer adhesives, acrylate/epoxy adhesives, ethylene acrylic acid adhesives, polyester adhesives, polyester/epoxy adhesives, polyolefin adhesives, epoxy/polyolefin  
15 adhesives, polyolefin rubber adhesives, polyamide adhesives, and combinations thereof;  
forming the at least one sheet so as to define an inflatable chamber having at least one structural seam formed by the two edges; and  
bonding a substantial portion of the at least one structural seam with the  
20 adhesive tape.

33. The method of claim 32, wherein the adhesive tape being provided is a backed adhesive tape, said forming step includes forming the at least one sheet so that the at least one structural seam has a butt joint geometry formed by the two  
25 edges, and said bonding step includes applying the backed adhesive tape so as to overlap the edges and bond the structural seam.

34. The method of claim 32, wherein said forming step includes forming the at least one sheet so that the at least one structural seam has a lap shear  
30 geometry formed by the two edges overlapping each other so as to form overlapping portions of the at least one sheet, and said bonding step includes

disposing the adhesive tape between the overlapping portions so as bond the structural seam.

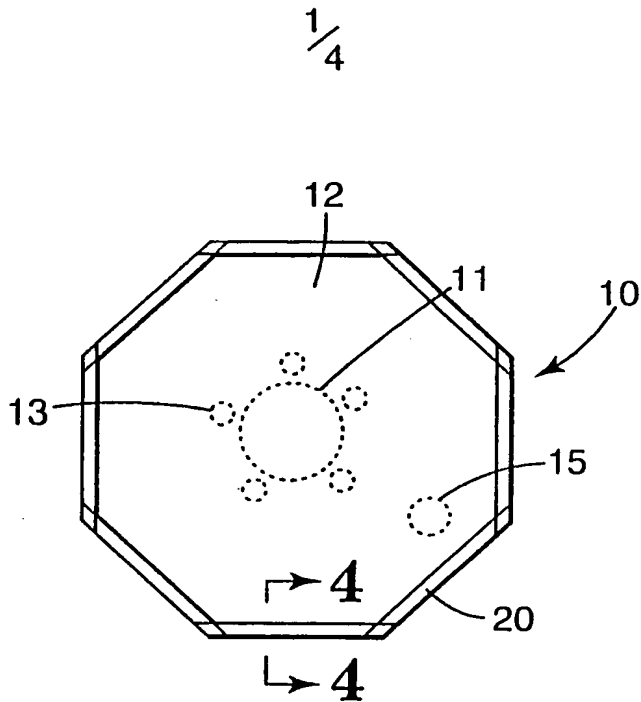


Fig. 1

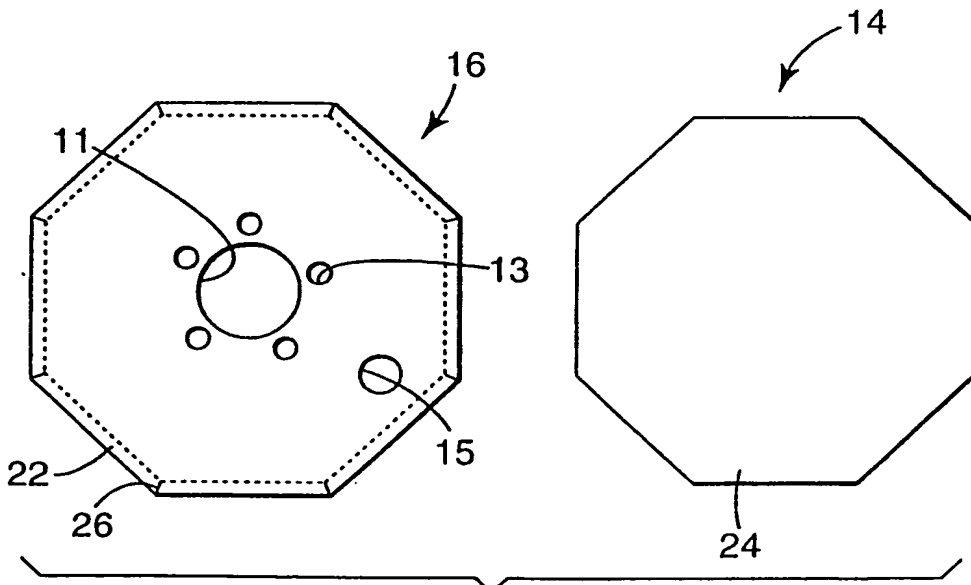
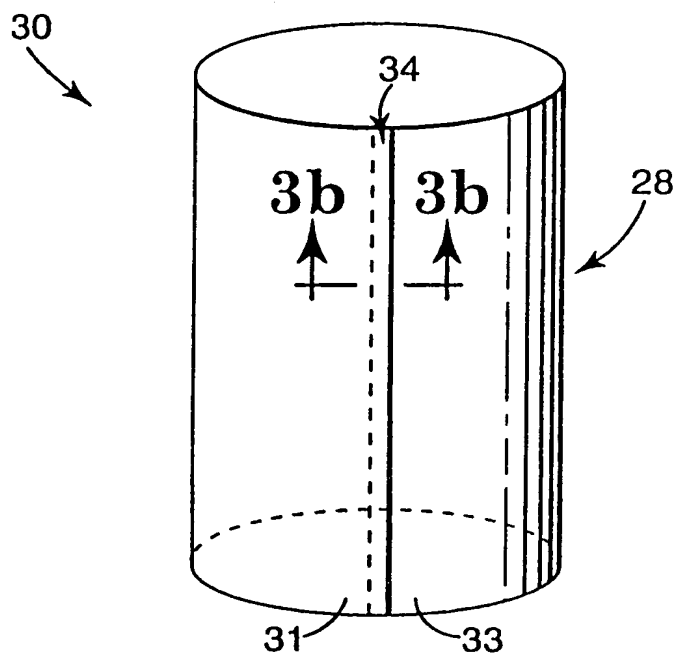


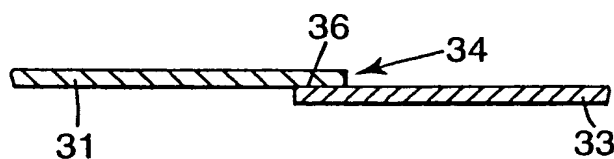
Fig. 2



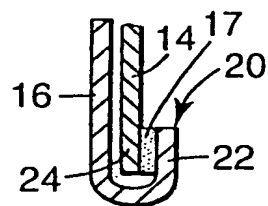
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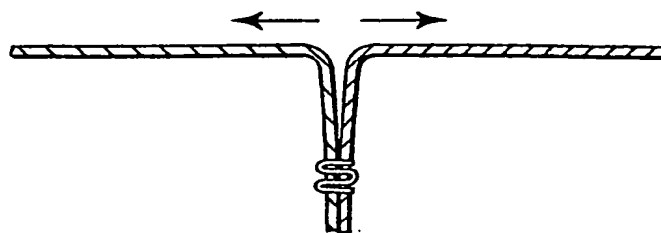
**Fig. 3a**



**Fig. 3b**

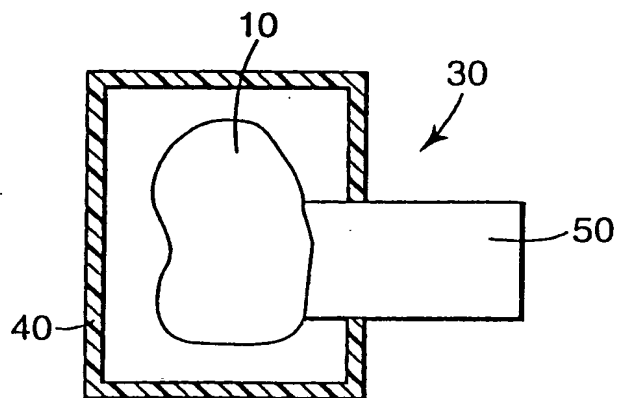


**Fig. 4**

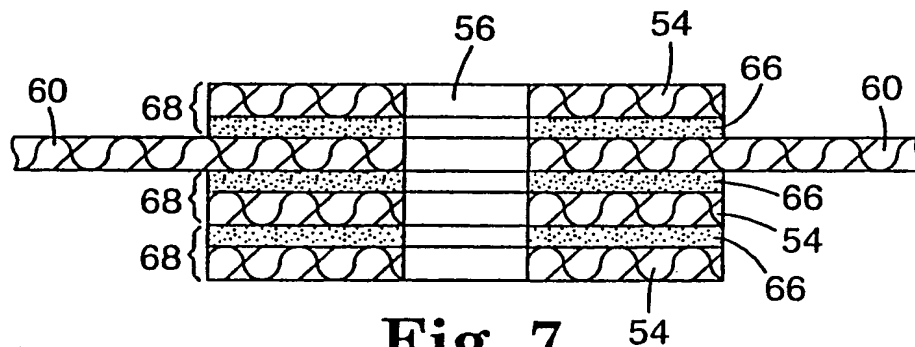


**Fig. 5**

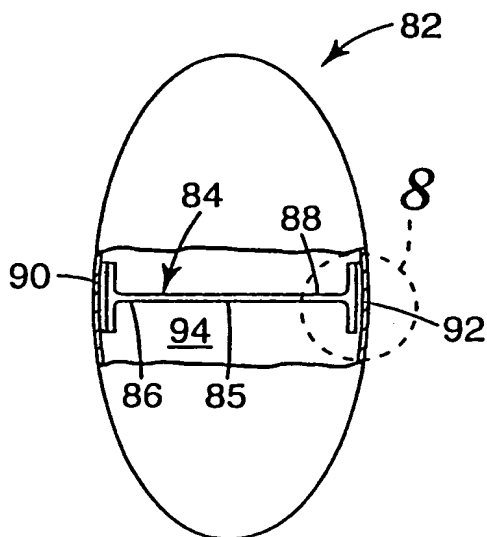
3/4



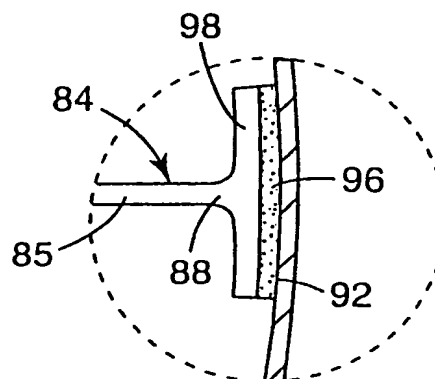
**Fig. 6**



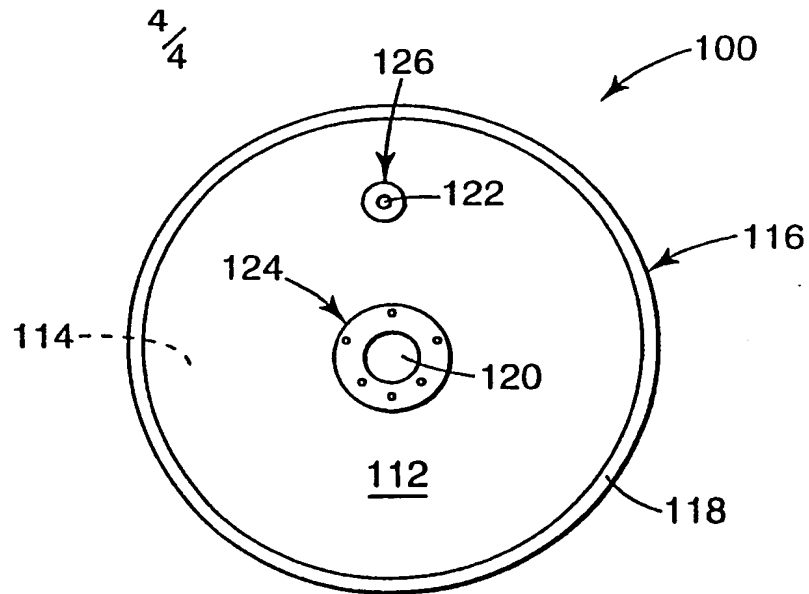
**Fig. 7**



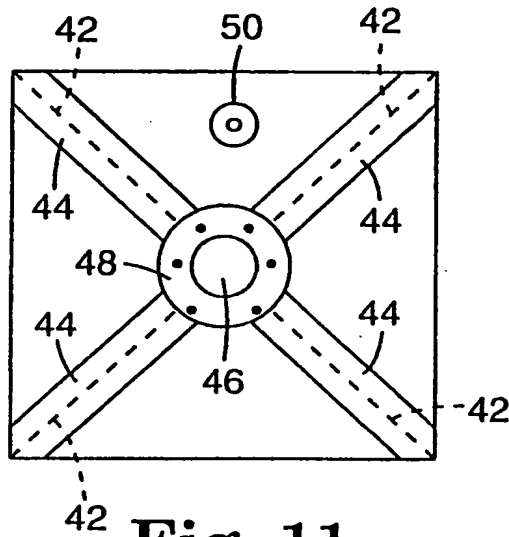
**Fig. 8**



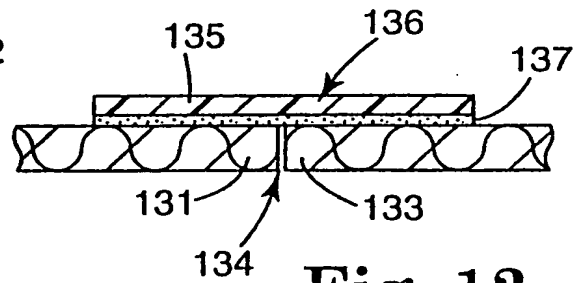
**Fig. 9**



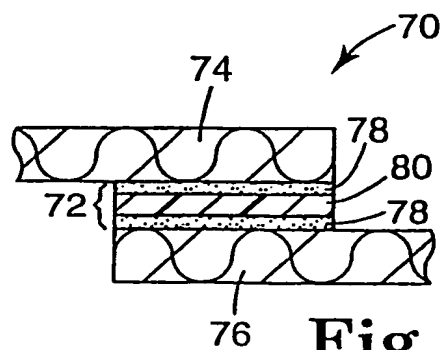
**Fig. 10**



**Fig. 11**



**Fig. 12**



**Fig. 13**

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/05238

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 B60R21/16

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 220 (M-1595), 20 April 1994 & JP 06 016099 A (TOSHIBA SILICONE CO LTD), 25 January 1994, see abstract	1-12, 14, 15, 17, 18
Y	---	19, 20, 22, 25, 27-29, 31, 32, 34
Y	EP 0 708 163 A (TOYO CLOTH CO., LTD.) 24 April 1996  see page 2, line 46 - page 4, line 9; figure 1 see page 4, line 20 - line 24; figure 4 ---	19-22, 25, 27-29, 31-34
	--- -/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

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Date of the actual completion of the international search

29 June 1998

Date of mailing of the international search report

06/07/1998

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## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 98/05238

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 222 (M-1404), 7 May 1993 & JP 04 356249 A (ACHILLES CORP ET AL), 9 December 1992, see abstract ---	19-21, 29,31-33
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 222 (M-1404), 7 May 1993 & JP 04 356248 A (ACHILLES CORP ET AL), 9 December 1992, see abstract ---	1-12,14, 15,17,18
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A	DE 43 06 696 A (PHOENIX AG) 16 September 1993 see column 1, line 3 - line 58; claims 1,2,4; figures 2,3 ---	28
A	US 5 482 317 A (NELSEN ET AL.) 9 January 1996 cited in the application  see abstract see column 9, line 13 - column 10, line 17; figures 6,7,15,16 see column 10, line 55 - column 11, line 4 -----	19,20, 22,25, 28,29, 31,32

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Information on patent family members

International Application No

PCT/US 98/05238

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